Aalto-yliopisto
Insinööritieteiden
korkeakoulu

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Improving the supply chain process between design management and procurement in a construction company

Thesis submitted for examination for the degree of Master of Science in Technology.

Espoo 01.07.2020
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Abstract of master's thesis

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Title of thesis Improving the supply chain process between design management and procurement in a construction company

Master programme Building Technology **Code** CIV

Thesis supervisor Assistant Professor Antti Peltokorpi

Thesis advisor(s) M.Sc. Hannu Surakka

Date 01.07.2020 **Number of pages** 108+15 **Language** English

Abstract

The construction industry has been facing challenges considering the process between design management and procurement in projects where prime contractor is responsible for design management, and design work is implemented possibly concurrently with construction. The activities between the parties play a major role in what kind of plans the design management can produce for the procurement and whether they are supplied on time. In its entirety, design management and procurement create the conditions in the chain for production to succeed later.

The objective of the thesis was to define effective and efficient supply chain process between design management and procurement for the target company in order to improve operations. Thesis was carried out as a design science research which consists of literature review and empirical part. Based on the literature, a theoretical framework was created for the supply chain process between design management and procurement, which serves as a basis and background information for the solution proposition. In the empirical part, the target company's databases were examined through and several interviews were held for mapping the present state of practices and identifying the challenges and problems as well as development targets considering the issue.

In the research, it was found based on interviews that there was no common process existing between design management and procurement in the target company. Activities were performed differently between different projects based on the habits experienced by the individuals as good. In addition, there was no consensus on the content of the required plans for the procurement, thus interaction and collaboration were missing. Since things can be practiced in many ways considering the topic in question, a development direction had to be chosen. The use of design and procurement packages was selected to be developed and collaboration between parties had to be improved. As a result of this thesis, a proposition for improving the supply chain process between design management and procurement was developed and created. A description of the process and a coordination tool for design and procurement packages in detailed design phase were created based on the research. The proposed process contributes to the more efficient supply of plans for the procurement at right time with the right content as well as improve collaboration between design management and procurement.

Keywords Construction industry, construction, business premises construction, procurement, design management, supply chain process

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Diplomityön tiivistelmä

Tekijä Henrik Zitting

Työn nimi Toimitusketjuprosessin parantaminen suunnittelun ohjauksen ja hankinnan välillä rakennusyrityksessä

Maisteriohjelma Building Technology **Koodi** CIV

Työn valvoja Apulaisprofessori Antti Peltokorpi

Työn ohjaaja(t) DI Hannu Surakka

Päivämäärä 01.07.2020 **Sivumäärä** 108+15 **Kieli** Englanti

Tiivistelmä

Rakennusala on kohdannut haasteita koskien suunnittelun ohjauksen ja hankinnan välistä prosessia projekteissa, joissa pääurakoitsija on vastuussa suunnittelun ohjauksesta ja suunnittelutyötä toteutetaan mahdollisesti samanaikaisesti rakentamisen kanssa. Osapuolten välisellä toiminnalla on suuri merkitys siihen, millaisia suunnitelmia suunnittelun ohjaus voi tuottaa hankinnalle ja toimitetaanko ne ajoissa. Kokonaisuudessaan suunnittelun ohjaus ja hankinta luovat ketjussa tuotannolle edellytykset menestyä myöhemmin.

Diplomityön tavoitteena oli määritellä kohdeyritykselle tehokas ja toimiva toimitusketjuprosessi suunnittelun ohjauksen ja hankinnan välille toiminnan parantamiseksi. Diplomityö toteutettiin suunnittelututkimuksena, joka koostuu kirjallisuuskatsauksesta ja empiirisestä osasta. Kirjallisuuden pohjalta luotiin teoreettinen viitekehys toimitusketjuprosessille suunnittelun ohjauksen ja hankinnan välille, joka toimii perustana ja taustatietona ratkaisuehdotukselle. Empiirisessä osassa tutkittiin kohdeyrityksen tietokantoja ja pidettiin useita haastatteluja nykytilan toimien kartoittamiseksi ja asiaan liittyvien haasteiden ja ongelmien sekä kehityskohteiden tunnistamiseksi.

Tutkimuksessa havaittiin haastattelujen perusteella, että kohdeyrityksessä ei ollut yhteistä prosessia suunnittelun ohjauksen ja hankinnan välillä. Toimet toteutettiin eri tavoin eri projektien välillä perustuen yksilöiden hyväksi kokemiin tapoihin. Lisäksi ei ollut yhteistä ymmärrystä hankinnan tarvitsemien suunnitelmien sisällöstä, joten vuorovaikutus ja yhteistyö puuttuivat. Koska asioita voidaan harjoittaa monin tavoin koskien kyseistä aihetta, oli valittava kehityssuunta. Suunnittelu- ja hankintapakettien käyttö valittiin kehitettäväksi ja osapuolten välistä yhteistyötä oli parannettava. Diplomityön tuloksena kehitettiin ja luotiin ehdotus toimitusketjuprosessin parantamiseksi suunnittelun ohjauksen ja hankinnan välillä. Tutkimuksen pohjalta luotiin kuvaus prosessista ja koordinointityökalu suunnittelu- ja hankintapaketeille toteutussuunnitteluvaiheeseen. Ehdotetun prosessin tulisi myötävaikuttaa tehokkaampaan suunnitelmien toimittamiseen hankinnalle oikeaan aikaan oikealla sisällöllä sekä parantaa suunnittelun ohjauksen ja hankinnan välistä yhteistyötä.

Avainsanat Rakennusala, rakentaminen, toimitilarakentaminen, hankinta, suunnittelun ohjaus, toimitusketjuprosessi

Foreword

This thesis has been commissioned by a certain large construction company from Finland. The topic of the thesis was found through a problem faced by company's management and the scope as well as objectives were defined and developed in a collaboration. I found out already from the beginning that although the topic was very interesting, it was at the same time very challenging and has been a problem for a longer time in the construction industry. Through the implementation of the research, I have had the opportunity to delve into the complex interface of design management and procurement, as well as to develop my own professionalism on the subject. Now that the thesis is completed, I can be extremely pleased with it.

I would like to thank my thesis advisor, M.Sc. Hannu Surakka, who was able to provide guidance and support regarding carrying out the writing work and forming the academic content of this thesis despite his own busy. His constructive feedback and practical support enhanced implementing the research work. In addition, I have received a lot of support from my manager, procurement manager Teemu Takala, and also from, head of developer contracting Jani Lehtola, who have provided professional guidance and support on the subject during the entire research. From Aalto University, I would like to thank my thesis supervisor Assistant Professor Antti Peltokorpi, who's guidance and supervision has been indeed beneficial and worthwhile in order to construct the research and examine the topic in a form of research.

Furthermore, I would like to mention thanks to all those who participated in the interviews and provided data for the research. I would also like to thank my very good friend and colleague, Niko Timonen, for exchanging thoughts and having peer support during the making of the thesis.

In the end, I would like to thank my family for their hard support and encouragement during my studies and especially my grandfather, Seppo Kivelä, for encouraging me to read as a Master of Science in Technology. My greatest thanks go to Linnea Kivekäs for her continued support and encouragement during my studies at Aalto University.

Espoo 01.07.2020

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Abbreviations

ACWP	Actual cost of work performed
BAC	Budget at completion
BCWP	Budgeted cost for work performed
BCWS	Budgeted cost for work scheduled
BEP	Building Information Modeling execution plan
BIM	Building Information Modeling
BOT	Build-Operate-Transfer
CBA	Choosing by Advantages
CMR	Construction Management at Risk
CPD	Collaborative Planning in Design
DB	Design-Build
DBB	Design-Bid-Build
DBOM	Design-Build-Operate-Maintain
DM	Dialogue Matrix
DSM	Design Structure Matrix
EIR	Employer's information requirements
EV	Earned value
HVAC	Heating, ventilation and air conditioning
ICE	Integrated Concurrent Engineering
IPD	Integrated project delivery
KSE 2013	In Finnish Konsulttitoiminnan yleiset sopimusehdot, General conditions for KSE 2013
LBDM	Location-Based Design Management
LOD	Level of Development
LPS	Last Planner System
MEP	Mechanical, electrical and plumbing
PPP	Public-Private-Partnership
RYHT 2000	General procurement and delivery terms for construction products
SBD	Set-Based Design
SUKE	In Finnish Suunnittelujärjestelmän kehittäminen, Development of a design system
SWOT	Strengths, weaknesses, opportunities, threats -analysis
Talo 2000	The Finnish Construction 2000 classification system
TFV	Transformation, flow and value generation concepts of design
TVD	Target Value Design
VDC	Virtual Design and Construction
YSE 1998	In Finnish Rakennusurakan yleiset sopimusehdot, General conditions for building contract

1 Introduction

1.1 Background

The process between design management and procurement in construction industry has been facing challenges in many companies when they are involved in projects where main contractor is in charge of design management. The flow of information and decisions taken jointly can be missing. Also, common practices and procedures can be missing among employees and projects. It is necessary to study the activities between both parties and develop cooperation in order to make the process better, which will lead to more effective and successful business and projects. According to Tzortzopoulos and Formoso (1999) multiple studies have emphasized the importance of design process of building construction projects in order to improve the performance of the construction industry. The process is very difficult to manage, and it includes thousands of decisions with several interdependencies under highly uncertain conditions. Design management and procurement are strongly linked when considering the performance of the whole construction project.

The topic of this thesis was found through a problem emerged in a construction company's supply chain process between design management and procurement. It was noticed in the target company, that supply chain process between design management and procurement needs to be improved. Procurement needs the necessarily plans at right time from designers to be able to make proper invitations for tenders. The situation was lacking performance and effectivity because there were no proper instructions for design management and procurement in which way the process should be driven in order to succeed. The supply chain process becomes incoherent when there is not known instructions what every party should do to fulfil the needs of other parties.

Procurement needs different kind of plans from different field designers for one procurement package, and the number of these plans and design fields varies depending on the project and field of the object which is procured. Procurement can include work, materials or services, or combination of them, and the order of different works at construction site will have an effect on order of the procured procurement packages. Nevertheless, certain procurement packages can usually contain roughly the same plans from different design fields. Design management, in turn, has their own design packages which are used to control and manage designing. Design packages are constructed in order to manage what plans should be ready at certain phases of the project, and the content and level of planning should be also described. However, the connection between procurement packages and design packages is missing at the moment in the view of procurement in the target company. Currently, designers supply the plans for the procurement either late or they are wrong at their level of planning or they are incomplete. Improvement in the supply chain process is desired in this area.

The current guidelines between design management and procurement in the company don't involve or editorialize Building Information Modeling (BIM) as the existing guidelines are several years old. Therefore, as the target company invests heavily in increasing the utilization of BIM, this thesis will be investigating also this point of view. At the same time, this

can act as a new arrival to the subject generally because it can be fresher and building information modeling management may not have been studied much relating to the chain between design management and procurement. Due to this, it is necessary to carry out this thesis.

Earlier research about the topic exists, such as a certain book which considers created SUKE-model for design management in Construction Management at Risk projects (Kruus & al., 2006). The book considers the relationship with design packages and procurement packages which strongly relates to this Master's Thesis' topic. Content and delivery of the plans are general problems in construction projects. Usually, plans are defective and late considering implementation of procurements and construction work. (Kruus & al. 2006, page 5.) Another example of existing literature is Koniel (2019) Master's Thesis which considers developing a design management method to eliminate detailed design waste. Koniel's Thesis concentrates on waste and lean design management practices and relates partly to this Thesis' topic. Both international and Finnish literature about the topic has been written and developed. Nevertheless, the point of view of prime contractor's procurement department is fragile and that is why this Thesis needs to be carried out.

The interface between design management and procurement has not been studied properly as existing research on the subject nearly always focuses strongly on either design management activities or procurement activities. As well, a proper determination of levels of development for building information model building components through procurement strategy and formats and its influence on the right content of plans and the level of planning has not been studied thoroughly. Lastly, design and procurement packages have been kept too separate entities, as procurement distribution has been allowed to make too freely and late, and their coordination has not been understood to be done by identifying dependencies of things and inconsistencies involving multiple aspects.

1.2 Objectives and research questions

The goal of this thesis is to define effective and efficient supply chain process between design management and procurement. The current procedures in the construction industry must be examined, and that way suggest a proposition to improve the supply chain process between design management and procurement. Development targets must be found and analyzed in order to provide sensible proposition for improvements. When the supply chain works, there is also much less waste and unnecessarily waiting in the process, thus productivity will increase.

Existing research often treats design management and procurement as too separate functions, leading to the fact that interdependencies between the parties are often overlooked, although for many things collaboration between design management and procurement is needed to keep the supply chain process intact and fluent. It is important to study the activities between the parties and their needs concerning the supply chain as well as to define the process between design management and procurement. As the interface between design management and procurement has not been studied deep enough and there are gaps regarding the issue in the research, it resulted into the following research questions:

- What are the problems and challenges in the supply chain process between design management and procurement?

- What kind of plans procurement needs from designers to be able to make proper invitations for tenders?

- What is the process by which design management can produce plans that serve procurement at right time?

    - What are the needs of both parties in order to make fluent working supply chain process?

    - How should design management and procurement collaborate to achieve the state that design packages and procurement packages would be sensible and aligned?

    - How Building Information Modeling can be utilized in the process between design management and procurement?

The scope of this thesis is limited to construction business with project models where prime contractor is in charge of design management. Research and thesis writing will be done from the view of prime contractor's procurement and the supply chain process will be limited to examine only the part of the supply chain between design management and procurement. Implementation of the proposed solutions is limited outside of this thesis' scope due to time limitations of the research. Thesis examines mainly business premises and competition construction, and residential construction is not considered.

1.3 Research methods

Due to the nature of this thesis problems, it was decided to use Design Science Research method to answer the company's goals and build proposition to solve the problems. While natural science is aimed at understanding reality, and its products and claims are evaluated against norms of truth, design science attempts to create things and solutions that serve human purposes. Natural science consists about first discovery and then justification, while design science consists about building valuable models and methods, and evaluation process. When design science products can be constructs, methods, models and implementations, it was noticed that it could provide improved solution for this thesis problems. (March & Smith, 1995.)

The goal of design science research is to produce knowledge through design artifacts and create those artifacts as well as implement. The design artefact can be characterized as a management intervention and is often framed as a solution to a problem faced by management. (Öhman, 2019, p.7.) This information supports also the decision of using the design science research as a research method for this thesis. When the desired goal is an artifact or recommendation, design science research method can be used for achieving satisfying solution for the problem. The designed artifact to solve problems is later evaluated in the method, what was designed, what is working or not and discuss the results. The method is problem solving focused and based on the understanding of the problem. Understanding the problem

well is necessarily for proper success of research. Even when the achieved solution is not optimal, the design science research method will obtain some kind of satisfactory solution for the problem. (Dresch, Lacerda & Antunes, 2015, p.67-68.)

Dresch, Lacerda & Antunes (2015, p.119.) recommends different steps for conducting design science research (Figure 1). The path for this thesis' design science research method was constructed by using this recommendation as help and instruction for conducting and creating the author's own research plan model.

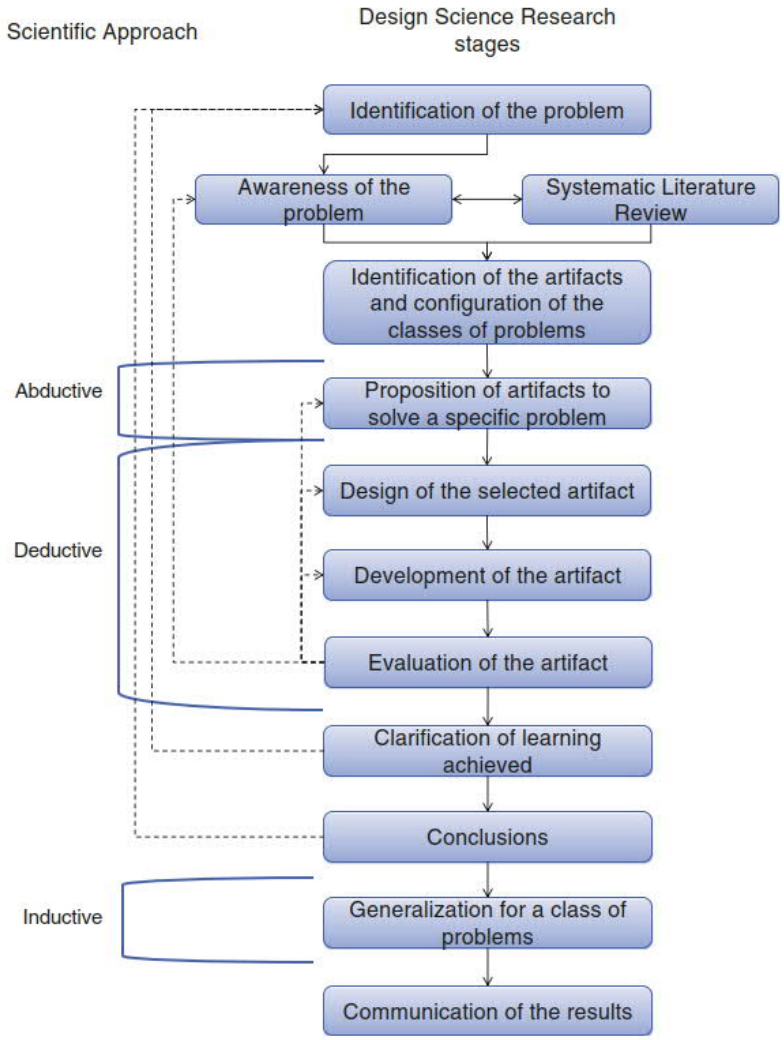

Figure 1. Proposed method for conducting design science research (Dresch, Lacerda & Antunes, 2015, page 119.)

Author's own composed research plan for the thesis is shown in the Figure 2 below. First the problem is identified, and goals are set for the research. The literature review is constructed into a form of text and theory by using different literature sources. The aim of the literature review is to provide a general understanding of the topic and to form a theoretical framework for the process based on earlier research and literature, which will be developed in the research section. The next step is to determine company's current procedure and development targets. For this, data search for company's existing materials is done, and interviews about present practices, challenges and problems as well as development targets are constructed, held and later analyzed. Development propositions from the literature review,

data search and interviews can be taken into account and later utilized in the development of the artefact and construction of proposition to solve the problem. When proposition is created and introduced, it will be evaluated. Evaluation process is done by evaluating reliability of the used data and holding few interviews. Finally, the generalization of the created solution will be considered in general for the construction industry.

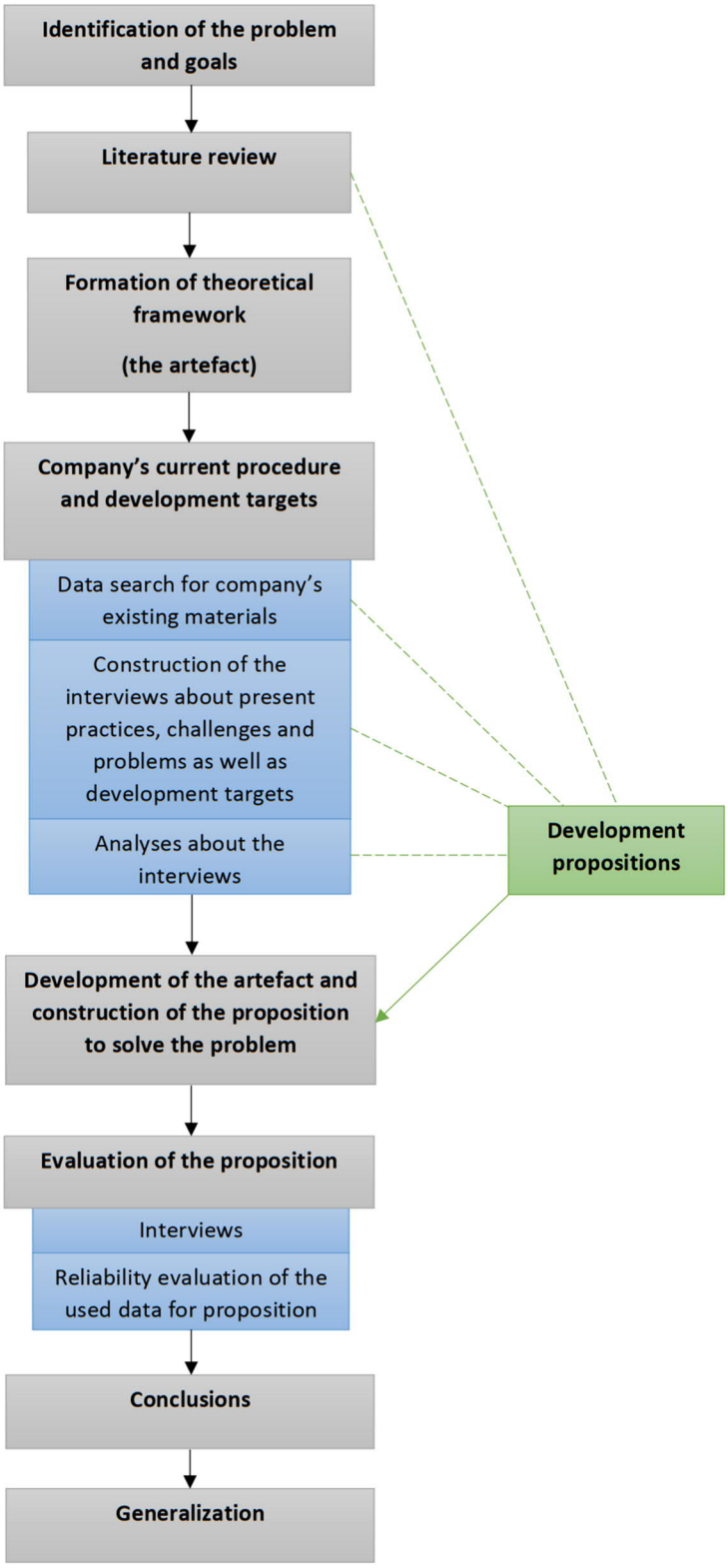

Figure 2. Research plan of the thesis constructed in a form of Design Science Research method

The chosen Design Science Research method was considered to be the best research method for this thesis as the problem of this thesis is complex and faced by management. Solution providing ability of this method is desirable and can lead to at least some kind of satisfactory solution. Different kind of constructing phases during the research, such as construction of interviews and proposition, will have an effect on the final success of the research, but they are tried to implement with help of thesis advisor and other company's advising management personnel. The suitability of the Design Science Research method can be discussed and stated in the conclusions phase.

1.4 Structure of the thesis

The structure of this thesis is divided into different parts and the first part consists of the literature review and theoretical background of the topic in question. Related topics, features and aspects will be presented to cover knowledge about the supply chain process between design management and procurement. Based on the literature review, a theoretical framework will be developed and formed for the supply chain process to support later the solution proposition for improving the supply chain process. The second part of thesis consists of mapping the present state of the company's practices, challenges and development targets including data search from company's databases and interviews. Company's databases will be searched for discovering existing materials and guidance about the topic. Qualitative interviews will be constructed and held based on the literature review to provide empirical knowledge about current practices, challenges and development targets related to topic.

On the basis of the literature review and present state of the company as well as interviews, a solution proposition to the problem will be created. Thus, the third part of this thesis consists of a proposition for improving the supply chain process which is created to solve the problem in question and improve the supply chain process between design management and procurement. In the end of this thesis, the proposition will be validated and evaluated also providing generalization for the use of proposition as well as the entire research will be discussed. Finally, conclusions will conclude the thesis and recommendations will be given for future research.

2 Literature review and theoretical background

This chapter contains a literature review of the supply chain process between procurement and design management in a construction company. The first subchapter (2.1) presents general stakeholders of a construction project and the second subchapter (2.2) introduces construction project phases, while subchapter (2.3) introduces different project delivery methods for construction projects. Subchapter (2.4) reviews generally design management while subchapter (2.5) concentrates on reviewing subjects related to procurement. Subchapter (2.6) presents the difference between supply chain process and project process as well as introduces generally supply chain management and internal supply chain process of construction company. Supply chain process between design management and procurement is reviewed more accurately at subchapter (2.7) and subchapter (2.8) concentrates on building information modeling aspects. The last subchapter (2.9) composes the author's conclusions about the literature review and theories.

2.1 Construction project stakeholders and management

In construction sector, project stakeholders can be defined as organizations, groups and individuals who are actively involved in the project. Stakeholders' interests can be positively or negatively affected by the activities or results of the construction project. (Olander, 2007.) Project manager has to manage and dealt with other groups of stakeholders. Identification of stakeholders and assessing stakeholders' interests and expectations throughout every phase of the construction project lifecycle are necessary for successful project management. Also, stakeholders' behavior and its effect on project outcome should be forecasted by the project manager. (Chinyio & Olomolaiye, 2010.)

Project stakeholders can be divided into two groups. The first group is often defined as internal stakeholder group and they are having a contractual relationship with the client or a subcontract from another internal stakeholder. They can be team members of the project or those who provide for the financing of it. The second group is usually defined as external stakeholder group and they are affected somehow by the project in significant way. Usually, they may have little choice about whether the project goes ahead and their opinion about the project can be negative or positive. Internal stakeholders can be divided forward into demand side and supply side, and external stakeholders into private and public as shown in the (Table 1) below. (Winch, 2007.)

Table 1. Example of project stakeholders (Customized based on reference: Winch, 2007.)

Project Stakeholders example			
Internal Stakeholders		**External Stakeholders**	
Demand Side	**Supply Side**	**Private**	**Public**
Client Financiers Sponsor Client's employees Client's customers Client's tenants Client's suppliers	Consulting engineers Prime contractors Trade contractors Materials suppliers Employees of the above	Local residents Local landowners Environmentalists Conservationists Archaeologists	Regulatory agencies Local government National government

Main stakeholders in construction projects can consist of owner/customer, user, construction project manager, prime contractor (construction company) and designers (Figure 3). Also, subcontractors, material suppliers, other consultants etc. can exist. These stakeholders' roles and tasks can vary a lot depending on the chosen project model and contracts. This will lead to the discovery that project organizations are usually complex and multi-professional.

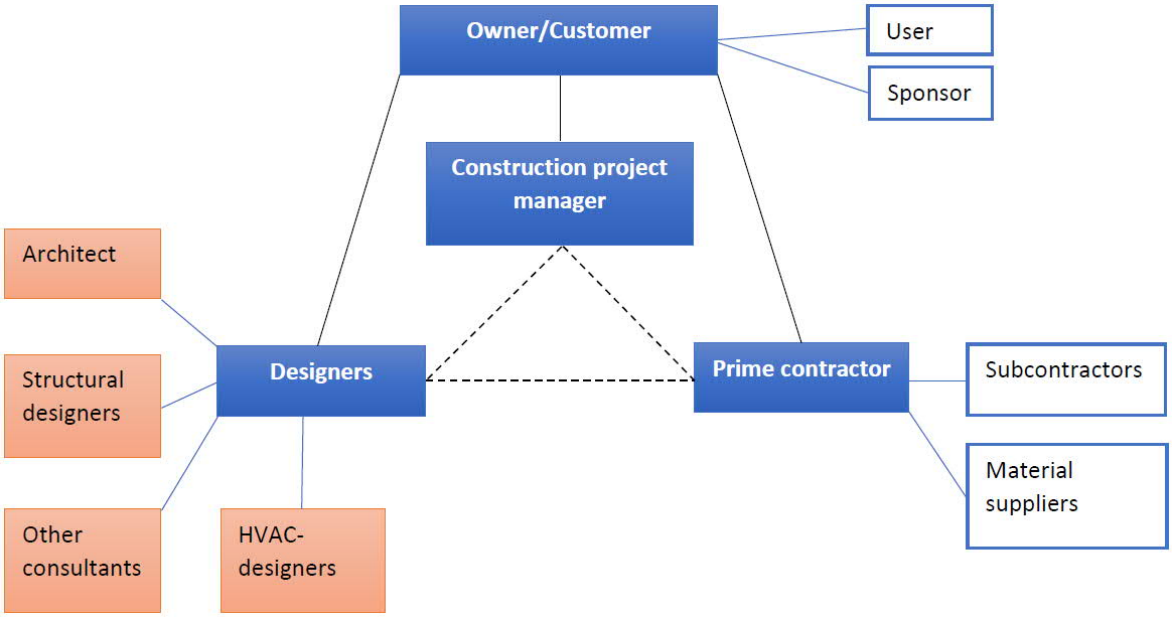

Figure 3. Example of main stakeholders in construction projects (Customized based on reference: Peltokorpi, 2018, lecture 1.)

Construction project management includes a set of objectives which may be accomplished by implementing phases of operations subject to resource constraints. Constraints are usually concerning human workforce and financial resources. There can be conflicts between scope, cost, time and quality in the project and that is why the balance and location between these objects must be managed by the project manager. (Santos, 2019.) Compromises must be made, and risks must be evaluated and selected to be taken. Without taking risks there are no possibility to make any gains or benefit from the project. Project management consist much of sharing the risks between contractual parties.

The tasks of construction project management can consist of setting quality, scope, time and cost objectives for the project and monitoring their fulfillment. Designers must be selected and needed design contracts prepared. Needed decisions have to be made in time and construction permits acquired. Project management has to select delivery method for the project, organize competitive biddings and prepare contracts. Also, construction work must be controlled, and time targets monitored. Project management is responsible for necessary control actions to the project when the project objectives don't meet the planned values. (Peltokorpi, 2018, lecture 1.)

Controlling costs of the project among budgeted cost for work performed (BCWP) calculations is important for successful project management. BCWP is also called as earned value (EV). With EV calculations project manager can forecast cost, time and work performance during the project. Project manager looks to the future with the present data and sees what control actions have to be made if the project continues with the present cost, time and work realization or if the project continues as planned and scheduled control actions are not

needed. Realized data is compared to the scheduled and planned data in a form of calculation and diagram. The primary data points for the calculations are budget at completion (BAC), budgeted cost for work scheduled (BCWS), actual cost of work performed (ACWP) and BCWP. (Karlos, Martinsuo & Kujala, 2006.)

2.2 Construction project phases

Construction project phases can vary a lot between different projects, and they can be implemented also sometimes parallel. The process through the phases can be iterative if there is need to return to the previous phases for some reason in the project. (Peltokorpi, 2018, lecture 1.) This leads to the fact that perfect order of construction project phases doesn't exist. The order of the phases is project specific and can be changed if it is necessary for the project. Construction project phases can be generally presented in the following order:

1. Needs assessment
2. Program planning
3. Design proposals
4. Master plan design
5. Construction permit tasks
6. Detailed design
7. Production planning
8. Construction
9. Start-up of operations
10. Period of guarantee.
    (Peltokorpi, 2018, lecture 1.)

Needs assessment is the first phase of the construction project where the needs of the owner are investigated and mapped. The need for space is determined and investigation report is made where the needed spaces are described, different options for spaces are presented and the cost of different solutions are evaluated. If the project is decided to start, this report works as a basis for future's work including presented estimations about scope, budget, quality, cost and schedule. After needs assessment phase comes program planning phase where opportunities to implement the project are investigated and evaluated more accurately. The final solution model for the construction project and scope, quality, cost and schedule targets are defined. Also, functional, financial and architectural targets are described. In the design proposals phase, architect and construction manager checks together initial data from program planning and then different initial design proposals are offered to the owner by design company or companies until owner selects the wanted design proposal to be executed. After this comes master plan design phase where master plans are designed for the construction permit and more accurate information about the exact location of the building is produced. Also, architectonic, functional and technical general solution is developed. Construction permit tasks phase includes applying construction permit for the building from the government. The necessary documents and master plans are sent for the government for further inspections and evaluation for granting the construction permit. This can happen with the help of construction manager and main architect. (RT 10-10387, 2001.)

Detailed design phase includes detailed and more specific designing for the building from different field designers. Different design fields are for example architect design, structural

design, HVAC design, electrical engineering and geotechnical engineering etc. Production planning phase contains the planning which must be made by the prime contractor in order to succeed with production and construction works in the agreed time schedule, scope, quality and budget. Prime contractor plans the implementation practices for different construction works and makes more precise schedules for work tasks and prepares construction, procurements and contracts. Before this, the bidding process for prime contractor must be done and prime contractor selected. Construction phase includes all construction works until the construction site is ready for delivery of the building for the owner. After delivery comes start-up of operations phase where the building is taken into use by the owner, user or other customers. Period of guarantee phase stands for the time period when the contractor is responsible for the warranties. (RT 10-10387, 2001.)

Often detailed design, production planning and construction phases are done parallel which emphasize the importance of systematic planning and working in order to avoid problems and delays in the projects. This parallel process can increase the performance of the project, decrease the construction time and costs or even force stakeholders into systematic implementation and continuous improvement but in the same time it makes everything more difficult and vulnerable when problems occur during the project. This aspect relates strongly to this Master's thesis' subject. The certain plans from design phases and different design fields have to be ready and available in correct time for procurement in order to be able to make successful procurements and contracts. The focus is on detailed design and implementation plans. Collaboration and communication between the design management and the procurement is essential.

2.3 Construction project delivery methods

The selection of suitable construction project delivery method is necessary for achieving a successful construction project. Project delivery method that is appropriate to be used for any construction project doesn't exist and therefore different project delivery methods are continuously developed. (Zuber & al. 2018.) All of them have their own advantages and disadvantages, however the purpose is to be able to first define the features of the project and by that select the most suitable project delivery method. Project delivery method is usually chosen by the owner or their construction project manager. The chosen project delivery method has a direct influence on the contracts, done by construction project manager/owner, between stakeholders and owner. It defines certain roles and responsibilities for the different stakeholders and determines also some of the risk sharing between the parties. Thus, it is intended to achieve targets and control risks. Different project delivery methods are differentiated based on the formation of contracts and technical relationships between the owner, contractor and designer (Zuber & al. 2018).

Project delivery method defines how project tasks and responsibilities are distributed for example with project management, design and procurement. Risk distribution between stakeholders involves cost, schedule and quality impacts of risks and is also defined by the delivery method. (Peltokorpi, 2018, lecture 2.) Project owner can choose the project delivery method based on the following features:

- What are the target priorities of the project? For example, cost, quality, functionality or flexibility during the project etc.

- What kind of own resources and capabilities owner has for the project?
- What kind of providers and resources are available?
- How complex the project is from technical perspective and is there need for collaboration?
  (Peltokorpi, 2018, lecture 2.)

There are three primary project delivery methods in use in construction industry. The first is Design-Bid-Build (DBB), the second is Construction Management at Risk (CMR) and the third is Design-Build (DB). DBB is probably the most widely used delivery method but CMR and DB are appeared as alternative methods since technical demands of new and complex systems require more coordination between the project team members. Also, possible improvements in cost and schedule performance and reduce in claims and conflict between parties led to emerge of CMR and DB. (Zuber & al. 2018.) There are other delivery methods existing as well like for example collaborative delivery methods Alliance and Integrated project delivery (IPD), and lifecycle delivery methods Design-Build-Operate-Maintain (DBOM), Build-Operate-Transfer (BOT) and Public-Private-Partnership (PPP). (Peltokorpi, 2018, lecture 2.) This Master's Thesis' subject and content focuses only in project delivery methods where prime contractor is in charge of design management, but different delivery methods are still introduced for understanding the big picture and difference between project delivery methods.

Design-Bid-Build

DBB is a traditional project delivery method which separates the project delivery process into three sequential phases (Zuber & al. 2018). First phase is the design phase where designer is selected by the owner and designing of the building is done. Second phase is the bid phase where prime contractor is selected and contract about construction works is made. Third phase is the construction phase where the building is built by the selected contractor. (Peltokorpi, 2018, lecture 2.) Primary reasons for the owner to choose DBB can be: retain control of design, procurement laws are well defined and low first cost (bidding). Disadvantages for the owner can be: final cost changes in owner's responsible, probably most litigious method and contractor has no input to project. (Gkkworks, 2013.) The owner or their construction manager consult is responsible for design management and project costs are deformed mainly already in the design phase when cost control of designing defines the budget. The contract between owner and prime contractor is made based on already chosen and made design solutions and implementation plans. (RT 10-11223, 2016.)

Construction Management at Risk

In CMR delivery method prime contractor commits to deliver the project within a specified schedule and price, either a fixed lump sum or guaranteed maximum price. Contractor has usually two different roles in CMR method, working as a consultant to the owner considering construction and cost during the pre-construction phase and as a prime contractor in the construction phase. CMR method allows better team integration as prime contractor integrates with the designer at the early stage of the design phase and project even though owner has separated contracts with designer and prime contractor. Prime contractor's participation can benefit the owner in scheduling, procuring and negotiating tenders, developing the correct estimation of construction cost, assessing the designer's plan for construction and coordinating numerous aspects of the work. (Zuber & al. 2018.) Primary reasons for the owner to

choose CMR can be: retaining control of design, contractor is involved early and flexibility to price the project. Disadvantages for the owner can be: owner responsible for changes, owner's qualification-based selection of contractor and architect may not take input from contractor during design. (Gkkworks, 2013.) Design management and procurements are directed collaboratively between the owner and prime contractor depending on how responsibilities are distributed in the contract between them.

Construction Management at Risk delivery method can be distributed into three different types based on central groups of tasks of construction project manager which are the following (Kruus & al., 2006, page 17.):

- Construction management (in Finnish Projektinjohtorakennuttaminen), including only project management consultant practices and separate organization is responsible for construction site management. Procurement contracts are made in the name of the owner.
- Construction management service (in Finnish Projektinjohtopalvelu), including construction manager consultant practices and construction site management responsibility. Procurement contracts are made in the name of the owner.
- Construction management contracting (Projektinjohtourakointi), including both construction manager consultant practices and construction site management responsibility but procurement contracts are made in the name of the prime contractor. The method differs from traditional methods in that way that all construction site tasks are procured from external companies and the owner has still final decision-making power about these procurements. The owner can still have separated construction manager consultant who takes care of interests of owner especially considering designing. In addition, construction management prime contractor can make design contracts in their name when they are for example totally responsible for design management.

(Customized based on reference: Kruus & al., 2006, page 17.)

Table 2 presents the groups of tasks of construction project manager in these three different CMR types.

Table 2. The groups of tasks of construction project manager in different CMR types (Customized based on reference: Kruus & al. 2006, page 18.)

	Construction Management at Risk				
Project setter	Owner	Owner	Owner	Owner	Owner
Design contract	In the name of owner	In the name of owner	In the name of owner	In the name of owner	In the name of prime contractor
Procurement contracts	In the name of owner	In the name of owner	In the name of owner	In the name of prime contractor	In the name of prime contractor
Construction site management	Owner or separated procurement	Owner or separated procurement	Prime contractor	Prime contractor	Prime contractor
Construction project manager tasks	Owner	Prime contractor	Prime contractor	Prime contractor	Prime contractor
Subject of the contract	No contracts	Construction manager service	Construction management service	Construction management service and construction	Construction project
Conditions of contract	No conditions	KSE 2013	KSE 2013	YSE 1998	YSE 1998
	↓		↓	↓	
	Construction Management		**Construction management service**	**Construction management contracting**	

Design-Build

In DB delivery method, a single entity signs a single contract with the owner to provide both design and construction services. DB encourages team collaboration and enables the possibility for early involvement of contractor to give input and take a part in the budgeting, financing, programming, assessing the design for constructability and cost of construction. If the designer is not directly contracted with the owner, the owner can have limited influence and control on the final design quality. (Zuber & al. 2018.) Functional objectives and project targets can work as a primary content of call for bids material (Peltokorpi, 2018, lecture 2). Construction manager should accurately express targets and goals of project in program plan and call for bids document to ensure good qualitative results. Quality could be emphasized instead of price in DB projects. (RT 10-11223, 2016.)

Collaborative delivery methods

In collaborative delivery methods competitive selection is integrated with collaborative and early selection of service providers from the view point of design. There is a bidding phase, development phase and implementation phase existing. Target cost is defined, and initial plans are collaboratively developed in the development phase. One feature from collaborative delivery methods is that underruns and overruns from the defined target price are allotted to the alliance parties. Collaborative way to manage challenges and opportunities together during the implementation phase can be beneficial for all parties. (Peltokorpi, 2018, lecture 2.) A good example of collaborative delivery method is project Alliance. Project alliance is a group formed from different field professionals and companies. The purpose is that different parties of the project sign a shared contract with the owner and form an alliance. Project risks and benefits are distributed as agreed in advance. The basic principles are trust, transparency, joint and several liability, and shared decision making. (Yli-Villamo & Petäjäniemi, 2013.) Alliance and IPD delivery methods have no big differences between them and they both are great methods for finding new innovations during complex and technically challenging projects. The development work of collaborative delivery methods is still in progress which means that general and collaborative agreed contract models doesn't exist yet, but the used contracts have been very similar from their content. (RT 10-11223, 2016.)

Lifecycle delivery methods

In lifecycle project delivery methods, there is an integrated partnership that combines construction and design responsibilities of Design-Build procurements with operations and maintenance. The entity is responsible at the same time for design, construction, long-term operation and also maintenance services. Lifecycle delivery methods are long-term relationships between owner and entity which can benefit both parties. The public sector can secure financing of the project and retains the operating revenue risk. (Peltokorpi, 2018, lecture 2.) Lifecycle models are suitable for big and large projects, and generating lifecycle project contracts and monitoring those have a big influence on project costs. The purpose is to make value for the customer during the whole lifecycle. Owner pays from the end product which has been ordered by owner. (RT 10-11223, 2016.)

Procurement responsibilities in project delivery methods

Procurement responsibilities in construction projects are dependent on the project delivery method. The chosen delivery method has an effect in who manages procurements or are they shared with collaborative way. The next Table 3 presents an example how procurement responsibilities may be distributed in different project delivery methods.

Table 3. Example of how procurement responsibilities are distributed (Customized based on reference: Peltokorpi, 2018, lecture 2.)

Owner manages procurements	Collaborative procurements	Contractor manages procurements
Design-Bid-Build multiple prime contractors (DBB)	Construction Management at Risk (CMR)	Design-Bid-Build single prime contractor (DBB)
	Alliance and Integrated project delivery (IPD)	Design-Build (DB)
	Public-Private-Partnership (PPP)	DBOM and BOT

2.3.1 Prime contractor in charge of design management

As DBB has still remained prevalent in traditional construction industry, some owners have been selectively adopting alternative delivery methods that enlarge collaboration between owner, contractor and designer. For example, DB delivery method has increased collaboration as contractor and designer act as a unified team to deliver a finished project at a set price. (Minchin & al. 2014.) In DB contracts, the design management responsibility is transferred to the prime contractor from owner's organization (Chan & al. 2005). With CMR delivery method contractor and designer are often engaged separately by the owner, however contractor is involved in the early stages of the design process and works collaboratively with designer to deliver the project to the owner (Minchin & al. 2014). CMR delivery method can be also used so that prime contractor is responsible for design management if it is contractual agreed. The owner transfers design management responsibility of detailed design work to prime contractor but retains decision making power about plans and procurements. With the use of CMR, the duration of the whole project is aimed to shorten, flexibility increased during development of plans, quality and price choices allowed and costs controlled and decreased. Prime contractor and owner manage the project collaborative, and detailed design, procurements and construction are overlapped by distributing construction work tasks into numerous procurements. (Kruus & al., 2006, page 11.) In lifecycle delivery methods, design management is usually under the responsibility of the prime contractor as the prime contractor is involved in the project its whole lifecycle. Furthermore, prime contractor's own established projects are also one example of project delivery methods where prime contractor handles design management. In own established projects, prime contractor is owner, construction manager and contractor at the same time and designing is usually purchased outside from design companies but design management is still at prime contractor. Before and during the project prime contractor seeks potential customer candidates for becoming tenant or purchasing the building. Prime contractor may also receive funding for the projects from customers in some cases.

In DB, Lifecycle and some CMR project delivery methods, prime contractor is responsible for the design management from the early start of the project, as well as in own established projects. This will bring contractor's opinions out about constructability and construction

work task orders, which strongly relates to the procurement process and collaboration between the design management department and the procurement department. This Master's thesis concentrates generating a solution proposition which can be utilized only in these project delivery methods.

2.4 Design management

Construction design is defined by Akbıyıklı and Eaton (2011) as following:

"Construction design is a specialised and highly demanding form of problem solving (Pressman, 1993; Lawson, 1997) where Stakeholders' needs and requirements are conceptualised into a physical representation of procedures, drawings and technical specifications (Freire and Alarcon, 2000). It is a dynamic and complex multidisciplinary process, performed in a series of iterative steps to conceive, describe and justify increasingly detailed solutions to stakeholders' needs (Sterman, 1992; Ogunlana et al, 1998; Baldwin et al, 1999)."

These mentioned procedures, drawings (plans) and technical specifications are needed for first understanding the designed solutions, when an outsider joins and involves into project, and second being able to implement and construct the designed solutions into real structures and objects. Thus, construction work can be expressed as converting designed plans into reality. Design process can be described as a process for generating value for customers, as a process of transforming inputs into outputs and as a flow of information through time and space (Koskela, Huovila & Leinonen, 2001). Construction design can be divided into different fields of designing. Construction design includes architect design, structural engineering design, HVAC design and electrical design, and many possible other fields of design depending on the project needs.

It must be recognized that design is a complex process and it is not linear. The process of design work doesn't always follow settled order due to the nature of design. However, design work is about understanding the problem and generating a solution for it by connecting gap to goal and in that way goal to the use and function for the client. (Pikas, 2019, page 129.) Pikas (2019, page 130) presents a good developed design process model considering the issue, which can be seen in the Figure 4. In the model, the design process entity is divided into four different quadrants named as conception, deliberation, mental, symbolic and external as well as perception/sensory experience. Transformation and decomposition are the two different types of mental actions relating to problem framing and solution framing stages, while regression and abduction are actions relating to solution generation and implementation stages in the design process. In the deliberation quadrant, analysis can be heuristic, thus it can lead to progressive iterations. This depends on whether the problem or solution is novel or not. However, in frequent design tasks, analysis becomes logic related and the mapping between the problem and solution areas has generally become stabled from function to structure. The designer wants to pay primarily attention to demonstration and prove that functional requirements have been met. Nevertheless, there is a bridging function when proceeding from designed details to components. When considering a design context, it is concerned with the translation of ideas into representations but when considering construction context, it is concerned with the production of components and constructability. It must be noticed that design solutions are often developed after the solution generation, thus there can

be a long way from the problem framing to the delivery and output phase in the design work. (Pikas, 2019, pages 129-130.) Outputs of the design work are often unique in construction industry because projects are unique and complex, thus there are not much similar buildings especially in Business premises construction. Nevertheless, some solutions can be standardized and utilized in different projects.

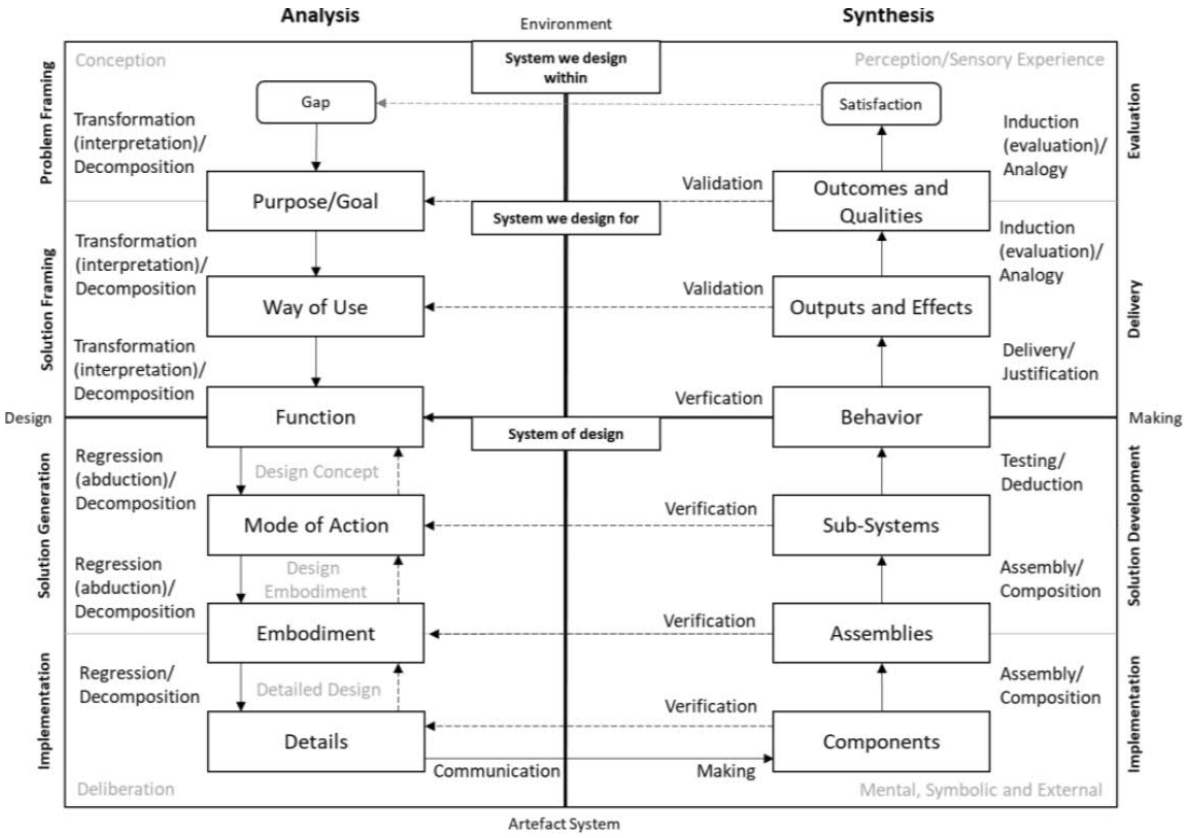

Figure 4. An example model of design process (Pikas, 2019, page 130.)

Design management is for ensuring, that design process leads to set targets and produces functionally, technically, economically, aesthetically and environmentally acceptable plans. (RT 10-11107, 2013.) Design management is responsible for administrative management of design work and customizing project's master schedule. Design management coordinates, monitors and controls design work for achieving set goals and targets. Schedule for design work is produced in a form of design packages by design management, and it sets targets and deadlines for what plans must be ready at certain phases and moments of the project. From the management point of view, design management is management by objectives and results, project management and management of specialist organization and customer relationships. (RT 13-10860, 2005.) Figure 5 presents example of design management and design group with different design fields. Coordinating different design fields together with the architect is one of the biggest challenges in design management that can produce difficulties. Likewise, determining the required level of planning and the plans as well as documents can be difficult for the design management, but it must be able to communicate this information to designers.

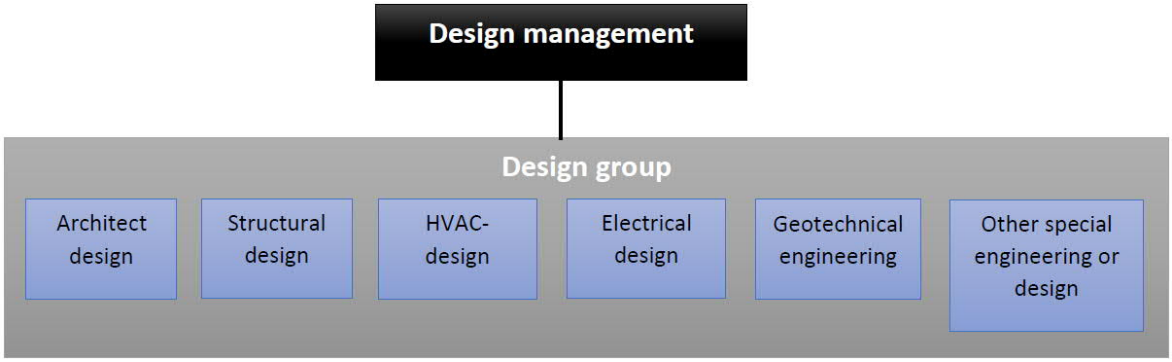

Figure 5. Example of design management and design group (Customized based on reference: RT 13-10860, 2005.)

Design management contains different phases during construction project. For example, Kruus & al. (2006, page 10) presents different main phases as program planning, master plan design and detailed design in SUKE-model (Figure 6).

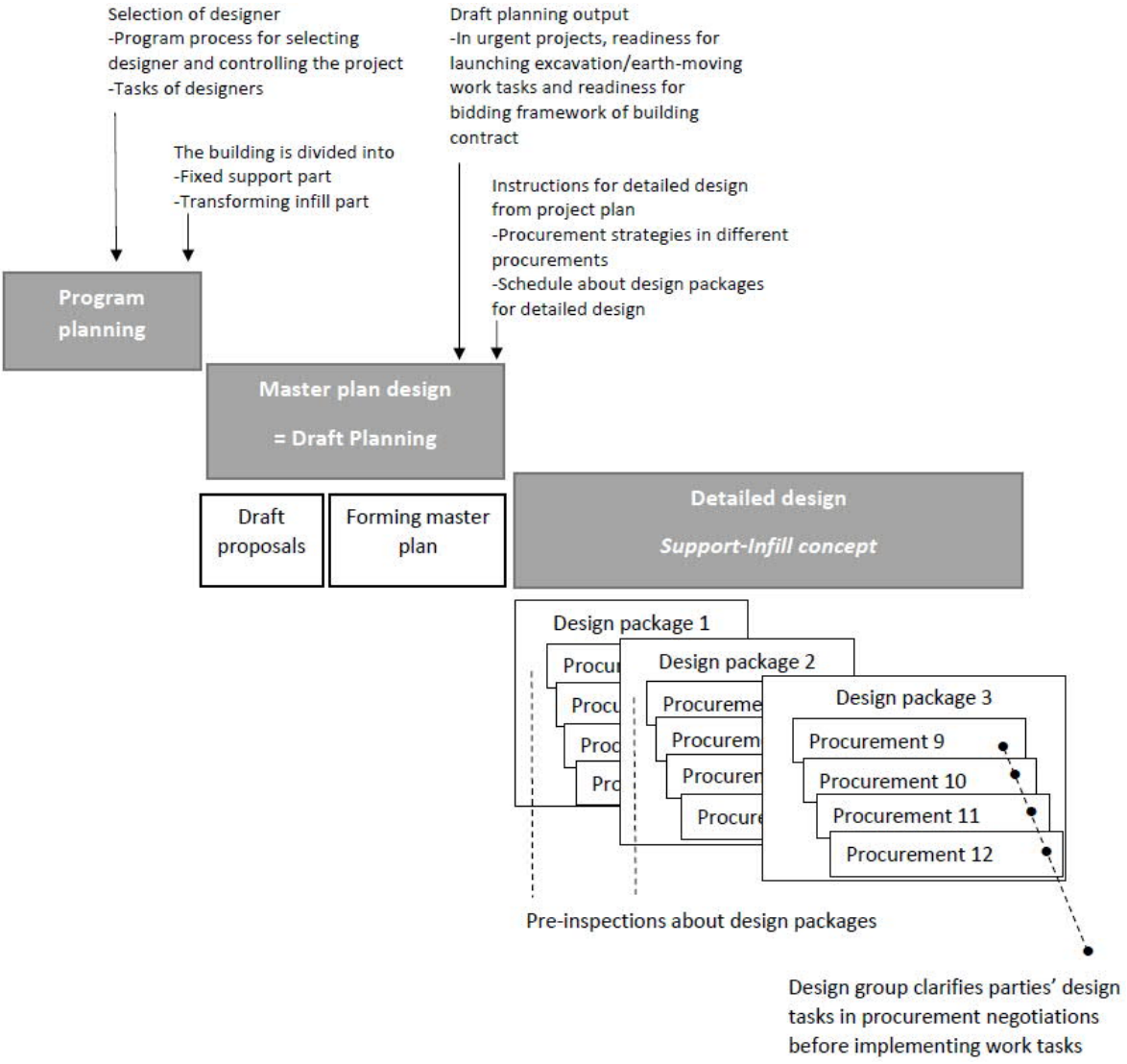

Figure 6. SUKE-model about design management phases and tasks (Customized based on reference: Kruus & al., 2006, page 10.)

2.4.1 General principles of SUKE-model

Design management SUKE-model was developed from certain theoretical starting points identified. Data and information transferring between all project stakeholders must be improved and know-how skills of the whole project team must be utilized as one entity. The design group cannot provide complete and flawless material for prime contractor/implementer, especially when needs for different plans for the project management and trade contractors are various. When plans are "shout" and demanded from every procurement package, it produces chaos for designers. Nevertheless, designers must prepare themselves for changes and sharpening of solutions in procurement phase. (Kruus & al., 2006, page 34.)

The purpose of SUKE-model is to combine design, procurement and construction, and allow overlapping over time. This enables the possibility for the owner to make decisions considering the project later than usually in construction projects. It is very beneficial when the users are not found yet, and the owner is not capable to make decision yet properly. (Kruus & al., 2006.) Nevertheless, this will challenge prime contractor's and designer's skills because project is more complex and vulnerable to problems and failures. Late changes in plans can cause changes in many things at construction site and procurement when considering construction work tasks' order and flow, and already made procurements which can lead to new unit prices from subcontractors and increased costs when the plans change. The challenge is to be able to stay in the original schedule and cost changes causes negotiations between the stakeholders. SUKE-model gives a lot of good advices how to control projects when there is uncertainty and late decision making, and survive through the complex project. The model aims to improve communication and collaboration between parties during the project implementation (Kruus & al., 2006, page 5).

General principles of SUKE-model are divided into following headings according to Kruus & al. (2006, pages 8-9, customized based on reference):

1. **Construction Management at Risk project's implementation as supplementing and overlapping.**
   Program plan produces flexible room program which is supplemented when draft proposals are made. Project plan is seen as supplementing document and risk analysis will be developing during progress of project. Detailed design, procurement and construction are overlapped.

2. **Phasing of the design process.**
   Design contracts are formed in two-parts with individualized reward and possibility to stop the task. However, changing the designer is not necessarily possible. Master plan designs are implemented as one entity and detailed design is purchased as continuous service during the construction.

3. **Dividing the designs into fixed support and transforming infill part.**
   Fixed support part and transforming infill part of the building are demarcated in the program plan due to wanted flexibility of transforming capability. Fixed support part plans are designed by sections in master plan design phase, and in detailed design phase transforming infill part plans are designed by space areas.

4. **Forming the schedule of designing with design packages.**

Plans are produced in design packages. Project management times design packages with "push" principle and construction site management both requests and instructs the plans and solutions for procurements with "pull" principle. Ballard Glenn (1999) describes push and pull principles as following: *"Push-based systems release work into production processes based on pre-established delivery dates and Pull-based systems allow work into production processes based on the state of the process."*.

5. **The readiness of plans in the invitation for tenders.**
Plans will be created as preliminary plans from their readiness unless other kind of demands are presented in the project plan and instructed to designers. The readiness of plans can be defined from design demands to detailed implementation plans in SUKE-model. The plans created by trade contractor will be checked and approved by owner's designers.

6. **Timing of structural plans.**
In urgent projects, detailed design will be started during master plan design phase. Plans for invitation to tender must be ready for excavation/earth moving and foundation contracts when decision about implementing construction is made. When it is decided in project plan, and also instructed for designers, that production subassembly contracting format is used with framework of the building, plans for the framework procurement must be also ready at that moment.

7. **The steering of design packages.**
Inspection about design package will be done and completeness, consistency and suitability for procurement and construction will be checked and ensured. Readiness, extent, content and delivery time of plans about every procurement package will be instructed to designers.

8. **The steering of procurements.**
Owner's designer checks and gives approval for production subassembly contracting trade contractor's designs and plans. In contract negotiations, the solutions and changes offered by production subassembly contracting contractor will be documented and contractor makes the changes into the plans. Contractor also maintains their plans and takes care of shifting the changes into the owner's plans.

(Customized based on reference: Kruus & al., 2006, pages 8-9.)

2.4.2 Processes of detailed design phase in SUKE-model

When the project phase proceeds into detailed design phase, procurement strategy and procurement plan is used define design schedule with design packages for the project. Distribution of procurements and decisions about procurements are included in procurement strategy and also instructions about abnormal procurement forms. In SUKE-model's detailed design phase, detailed plans are created in design packages and delivered. Design packages are inspected in inspections, design documents for procurement are delivered, and checkup and approval tasks demanded by procurement are taken care of. SUKE-model utilizes combined "push and pull" principle in detailed design phase and design management is treated as push controlling until the inspection of design packages. After that design management is treated as pull controlling. In this case, push means that project management, responsible for design

management, schedules and instructs design packages and demands sticking in the schedule. While, pull means that construction site management defines and instructs contents and timings of procurements' invitation for tenders plans. (Kruus & al., 2006, pages 33-34.) Figure 7 presents "push and pull" principle for design management.

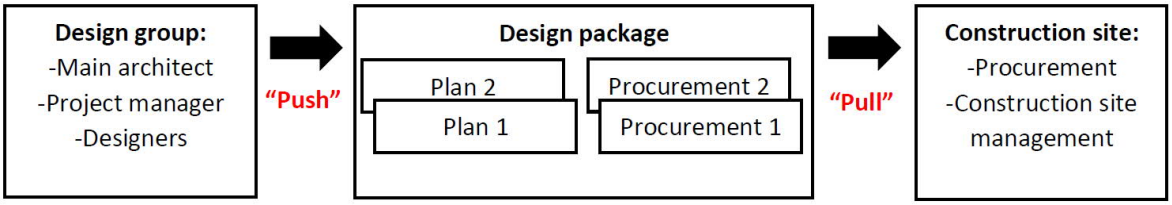

Figure 7. "Push and pull" principle for design management in SUKE (Customized based on reference: Kruus & al., 2006, page 34.)

2.4.3 Lean design management

Lean thinking strives to reduce order-to-delivery time by eliminating waste and creating value in an organization. Different industries have applied Lean principles in their procedures and manufacturing. Construction industry has also started to apply Lean thinking into production and business recently. However, there is still much room for improvement. With Lean ideas, different organizations can develop their business and processes towards better performance and provide better value for customer. While giving customers exactly what they want, the least amount of energy, time, effort, capital, equipment, materials and facility space is used. (Womack and Jones, 2008.)

Womack and Jones (2008) defined five basic principles for Lean. The first one is to **specify value**. Only ultimate customer can define value, and value is distorted by pre-existing organizations, for example engineers and other experts, who add complexity of no interest to the customer. The second principle is to **identify the value stream**. All the actions needed to bring a product to the customer create together the value stream, thus duplicate steps must be removed from the process. The third one is **flow** meaning that value-creating steps must be made to flow, and departments that execute a single-task process on large batches must be eliminated. The fourth principle is **pull** and it refers to that you must allow the customer to pull the product from you. You sell one and you make one. The last principle is to **pursue perfection**. The end doesn't exist for the process of reducing cost, time, space and mistakes, thus continuous improvement is the target. (Womack and Jones, 2008.)

Lean principles are originating from Toyota Production System principles and Toyota executive Taiichi Ohno (1912-1990) identified seven types of waste found in any process according to Womack and Jones (2008). **Transportation** considering unnecessary transport of parts under production and **inventory** considering stacks of parts waiting to be completed or completed products waiting to be delivered. **Motion** including unnecessary movement of people when working on products and **waiting** considering unnecessary waiting by people to begin the next step. **Over-processing** the product with excessive steps and **over-production** of products not needed as well as **defects** in the product. (Womack and Jones, 2008.)

In earlier literature considering concurrent engineering, three concepts of design were integrated shown in the Figure 8. The first concept is design as transformation which considers

transforming requirements and other input information into product design. The second concept is design as flow which considers flow of information composed of transformation, inspection, moving and waiting. Finally, the third concept is design as value generation which considers process where value is created for the customer through fulfilment of customer's requirements. As combined, these all are forming the TFV concept in design. (Anumba & al., Chapter 2 Koskela, 2007.) TFV concept has given some theoretical foundations for Lean design management.

	Transformation concept	*Flow concept*	*Value generation concept*
Conceptualisation of design	As a transformation requirements and other input information into product design	As a flow of information, composed of transformation, inspection, moving and waiting	As a process where value for the customer is created through fulfilment of his requirements
Main principles	Hierarchical decomposition; control of decomposed activities	Elimination of waste (unnecessary activities); time reduction, rapid reduction of uncertainty	Elimination of value loss (gap between achieved value and best possible value), rigorous requirement analysis, systematised management of flow-down of requirements, optimisation
Methods and practices (examples)	Work Breakdown Structure, Critical Path Method, Organisational Responsibility Chart	Design Structure Matrix, team approach, tool integration, partnering	Quality Function Deployment, value engineering, Taguchi methods
Practical contribution	Taking care of what has to be done	Taking care that what is unnecessary is done as little as possible	Taking care that customer requirements are met in the best possible manner

Figure 8. Transformation, flow and value generation concepts of design (Anumba & al., Chapter 2 Koskela, 2007.)

Tzortzopoulos and Formoso (1999) introduces some considerations on implementation of Lean construction principles in the design process. The share of non-value adding activities must be reduced while output value increased through systematic consideration of customer requirements. Some degree of flexibility in the end product must be allowed, thus output flexibility has to be increased. However, process variability should be reduced in the design work and cycle times must be reduced in order to make design work as effective as possible, though allowing the nature of the design work. The design process must be simplified by minimizing the number of steps, parts and linkages, while process transparency has to be increased in order to make sufficient communication of the process content possible. The focus should be on complete process in the design work and constructing continuous improvement into the process is essential. The flow improvement should be balanced with conversion improvement. (Tzortzopoulos and Formoso, 1999.)

There are different attributes which can be used in Lean design management at construction. Table 4 shows an example of attributes of Lean Design Management and contains research information about their use within different companies (Uusitalo & al., 2017).Attributes can be first divided into categories such as social process, methods and tools/technologies, and they all contain different possible practices which can be chosen for the use in design management. Social process category contains LPS, Big Room, Co-location, ICE and CPD. Methods category includes LOD, LBDM, TVD, SBD, CBA and real-time cost estimation.

Tools/Technologies category contains VDC, DSM, DM, A3 report and scrum. (Uusitalo & al., 2017.)

Table 4. An example of attributes of Lean Design Management (Uusitalo & al., 2017.)

Attributes of Lean Design Management	Veidekke	Skanska Norway	Rambøll	Skanska USA	Mini Case 1. HerreroBoldt	Mini Case 2. Sufolk	Case 1 to be tested	Case 2 to be tested	Case 3 to be tested
1. SOCIAL PROCESS									
LPS	X	X	X	X	X	X	X	X	X
Big Room	X	X		X	X	X	X	X	X
Co-location					X				
Integrated Concurrent Engineering (ICE)	X	X					X		
Collaborative Planning in Design (CPD)	X								
2. METHODS									
Level of Detail (LOD)						(X)		X	X
Location-Based Design Management (LBDM)					(X)				
Target Value Design (TVD)				X	X				X
Set-Based Design (SBD)			X	X			X		
Choosing by Advantages (CBA)							X		
Real-time cost estimation						(X)		X	
3. TOOLS / TECHNOLOGIES									
Virtual Design and Construction (VDC)	X	X	X	X	X	X	X	X	X
Design Structure Matrix (DSM)				X			X		
Dialogue Matrix (DM)	X	X					X		
A3 Report					X				
Scrum			X						

2.5 Procurement

Finding a satisfactory definition of procurement has been challenging, as many sources have disputed its definition in general. Even many words like procurement, purchasing and acquisition have been used to describe the same thing. For example, coherent boundary between the terms procurement and purchasing have not been found in the literature (Münch, 2015, page 42). It has been discovered that some sources comprehend that purchasing is a subset of procurement and based on transactions happening in the end of procurement process (Münch, 2015, page 43). Nevertheless, in this Master's thesis these terms are used to describe mostly the same thing because purchasing can be also understand as only direct buying from external sources, which is not always the purpose of company's procurement department. The procurement department can be understood, for example, as a company's organization unit which is responsible for all operational and strategic, procuring-relevant planning, activities, processes, strategies and interfaces (Münch, 2015, page 42).

However, there are different definitions for the term procurement. Novack and Simco (1991) define procurement as *"the act of buying goods and services for a firm"* or *"the activity of obtaining goods and services for the firm"* and state that *"procurement is a complex process that is difficult at times to define, understand and manage"*. Mak (2014), in turn, defines procurement as *"a careful, usually documented process resulting in delivery of goods or services to be delivered within a set time period"*. Rowlinson & McDermott (2005, page 3) instruct that procurement has been also described as *"the framework within which construction is brought about, acquired or obtained"*. Probably, it would be good to define the term procurement also as *"managing the outsourced resources of the organization"* (Surakka, 2018, page 18); (Kolhonen & al., 1997, page 5). As a conclusion, procurement is a big universal term for managing and leveraging external resources as well as the supply chain.

2.5.1 Procurement in the construction industry

The purpose of procurement department in a construction company is to purchase services and materials of the right quality, in right quantity and at the right price. The time for purchasing must be also right and the purchasing source. The aim is to seek to obtain the highest-quality subcontractors and materials at lowest possible price for the construction project. The procurement department supports the project team in performing their responsibilities within the project's scheduling goals and budgetary. Procurement department's engineers determine the best services, bulk materials and commodities, select the suppliers of materials or service, negotiate the lowest price and best terms for contracts, and make contracts ensuring that the right amount of the service or material is received at the appropriate time. In order to purchase services competitively and rationally, suppliers are evaluated based on the quality, price, availability, performance, reliability and service support. Also, financial backgrounds of the possible subcontractors or material suppliers are reviewed in order to prevent unnecessary risks. (Benton and McHenry, 2010, pages 28-29.) Procurement is an overlapping function between design and construction phases, and because of this, procurement risks may have cascading effect on project schedule and cost overruns. Therefore, management of procurement risk is important to avoid injurious effect on the success of project. Multiple items from multiple suppliers as well as several subcontracts with multiple subcontractors are required for a construction project under multiple contracts, terms and conditions and risks exposure. (Dixit, 2020.) Thus, evaluating and managing procurements and their risks are essential.

Benton and McHenry (2010, pages 29-30) describe some several main objectives for procurement department. The project team must be supported in implementing their responsibilities within the project's scheduling targets and budgetary goals. Inventory investment must be kept to a minimum meaning that just-in-time purchase concepts should be implemented. It is recommended that maximum integration with upstream and downstream supply chain members would be achieved and patterns of administration for procuring subcontracts, materials, services and equipment must be prepared. It is important that services are purchased and procured competitively, and good relationships with suppliers and subcontractors are developed and maintained. However, reliable alternative subcontractors and suppliers should be developed too, and background checks on current and potential subcontractors and suppliers must be carried out. It would be essential to establish and update database of current and potential subcontractors and suppliers. Nevertheless, subcontractors and suppliers must be prequalified, selected and evaluated in the process. Thus, the scope of work for each active project has to be studied, invitation for tenders reviewed and evaluated, successful and unsuccessful tenders informed, contract and associated details prepared and negotiations with potential subcontractor candidates must be held. Procurement orders, contracts, and subcontractors for engineering and construction have to be prepared, as well as delivery and transportation scheduled with construction site management. (Benton and McHenry, 2010, pages 29-30.)

The influence of procurements is economically big as material and subcontracting costs form a majority of construction project's costs. Procurement department is important also in the point of view of construction site management, because needed materials and services have to be delivered at right time in right place. (Jaatinen, 2016, page 14.); (Kokki & al., 1981b.) Procurements have a significant impact on project costs and delays in critical procurements can provide delays also to the whole project (Pelin, 2009). Construction site management

can only control and monitor project's costs, and minimize appearance of unnecessary costs, but the greatest part of costs is agreed and locked already when contracts are awarded. This will lead also to the subject that almost all procurement activities have the potential for increasing profit through cost reduction (Benton and McHenry, 2010, page 33). Thus, tendering is an integral part of procurement. Invitations for tenders are send to several selected subcontractor candidates, and that way negotiate in negotiations the best option for the project and procurement in question. (Jaatinen, 2016, page 17.); (Kankainen & Särkilahti, 1992); (Pekkala & Pohjonen, 2014) The aim is to utilize competition in order to use funds efficient and that way obtain the best possible value for money in a form of products and services (Jaatinen, 2016, page 17.); (Pekkala & Pohjonen, 2014). International sourcing should be also considered through tendering, as it can pressure prices more competitive in Finland and many international companies can be very skilled, competitive and considerable for subcontracting and supplying purposes.

Procurement can include subcontracting, materials or service, or different combinations of them. There is a difference between subcontracting and material purchasing. Subcontracting is usually complex relationship between prime contractor and subcontractor, and routine materials purchasing is transactional. If the chosen material supplier fails to perform, the material supplier's contract can be easily cancelled, but selecting the wrong subcontractor may be irreversible or very difficult. Finding another subcontractor for replacing the original can be very difficult and probably leads to increase of costs. (Benton and McHenry, 2010, page 44.)

In Finland, there is YSE 1998 General conditions for building contracts available for making and supporting contracts, thus the procurement department can refer to it in their subcontracts (RT 16-10660en, 1998). General conditions for building contracts have been created for building contracts between enterprisers. The YSE 1998 terms and conditions are intended to apply throughout the contract chain and they are also suitable for side and subcontracting without modification. Ready-made standard terms and conditions make it easier and faster to award a contract. The use of YSE 1998 terms and conditions in the awarding a contract is recommended, as the jointly developed standard terms and conditions have been created by representatives of both parties to the contract and the conditions are in principle fair. The case law of the construction industry is also largely shaped by the application of these conditions. (Peltonen, 2014.) In the same manner, for material procurement contracts, there is RYHT 2000 General procurement and delivery terms for construction products available for making contracts about supplying materials (RT 17-10721 EN, 2000). The RYHT 2000 terms and conditions are also jointly agreed standard terms and conditions, and they are generally applied in the construction industry in supply and procurement contracts between a buyer and a supplier. In practice, the role of the buyer is either at the contractor or the owner's construction manager depending on what is the project delivery method. (Marjasuo, 2012, page 12.)

2.5.2 Construction procurement categories and process

There are generally different kind of procurements related to construction projects and their implementation. In the same way, there are various procurement contract basis for different purposes of use. For example, there are nonrecurring contracts, year contracts, frame con-

tracts and partnership contracts. Nevertheless, procurements can be categorized into different categories based on the contents of procurements and the design need of procurements, thus procurements can be divided into subcontracts, construction products and materials, small and inventory purchases as well as purchase of services (Junnonen and Kankainen, 2012).

The use of subcontractors in construction has been spread widely as a result of nature and structure of the complex construction industry. The workload is versatile by type, function, form, size and production method as well as materials used, thus the implementation of tasks likewise requires the services of several different subcontractors and specialists. Prime contractors usually undertake only part of the construction operations required for themselves, since it is economically irrational for them to retain all the trades and specialization of the industry. (Edum-Fotwe, McCaffer & Majid, 2011, page 3.) Subcontract is a combination where installation work and materials are purchased from the same trade contractor. The amount of materials and installation works varies greatly in different subcontracts and it is also possible to procure only installation work when purchaser delivers the needed materials by itself. Thus, subcontract procurement can include work, material or service. In subcontracts, demands are set for the materials and installation work and they are mainly about quality and timing. In subcontract procurements, it is essential to ensure interference free progress and correctness of work. Construction product and material purchases are made through a sales contract, and the object of this kind of contract is the transfer of ownership of the product or material from the seller to the buyer. The demands are mainly set for product's details and delivery time. (Junnonen and Kankainen, 2012, page 7.)

Season/year contracts are strategic part of procurement, where company's procurement department and trade contractor has made for example one-year lasting contract about delivery of products or services with certain price or discount, and usually company commits to purchase at least a certain amount of these products or services (Junnonen and Kankainen, 2012, page 12). Large construction companies can use their purchasing power to get good prices from this kind of contracts because usually they have many projects which will use for example same material products, thus the amount of materials to be purchased is large.

Another contract type is a frame contract where a frame for the contract is created for future orders and the contract shall be supplemented by annexes. Recording things to annexes allows them to be developed and updated without the need to renew the entire contract due to changes. The most important basic things to be recorded in the contract are the description of the product and service, quality assurance, cooperation, joint development work and pricing principles. Because procurements are based on project-specific product and production plans, the content of deliveries and executions is different in different construction sites. (Junnonen and Kankainen, 2012, pages 22-23.) It has been recognized that, for example, HVAC-systems or steel structures can be such services or products that could need more profound partnerships in a form of frame contract (Kolhonen & al., 1997, page 20).

Webb (2017) presents Peter Kraljic's Matrix in Figure 9 which has been the original supplier segmentation model for supply chain management and procurement. Business-level procurements can be categorized with help of this portfolio analysis matrix in question. It is divided into two dimensions which are profit impact and supply risk. Non-critical items have a low impact on profit and are low on their risk meaning that these products are usually standardized, while leverage items have a high profitability but they are low on their risk, thus buyers

use their purchase power in these cases. Bottleneck items have a high risk, but profitability is low, thus sometimes the market structure forces buyers to accept an unfavorable deal when prices are forced upward when there are only few suppliers available in the market. Strategic items have a high risk and high profitability, thus development of long-term relationships can be beneficial. (Webb, 2017.) All these categories demand different procurement strategies and they require different attitudes and background work from the procurement personnel. When interpreting this matrix, it must be remembered that project delivery methods will have an effect on how much similar designs and materials are used or not. For example, housing construction companies can use same designs and materials in their own established building projects to achieve advantage in procurements, but in CMR methods the design solutions and material choices differ a lot, thus leverage item procurements cannot be used so much as advantage.

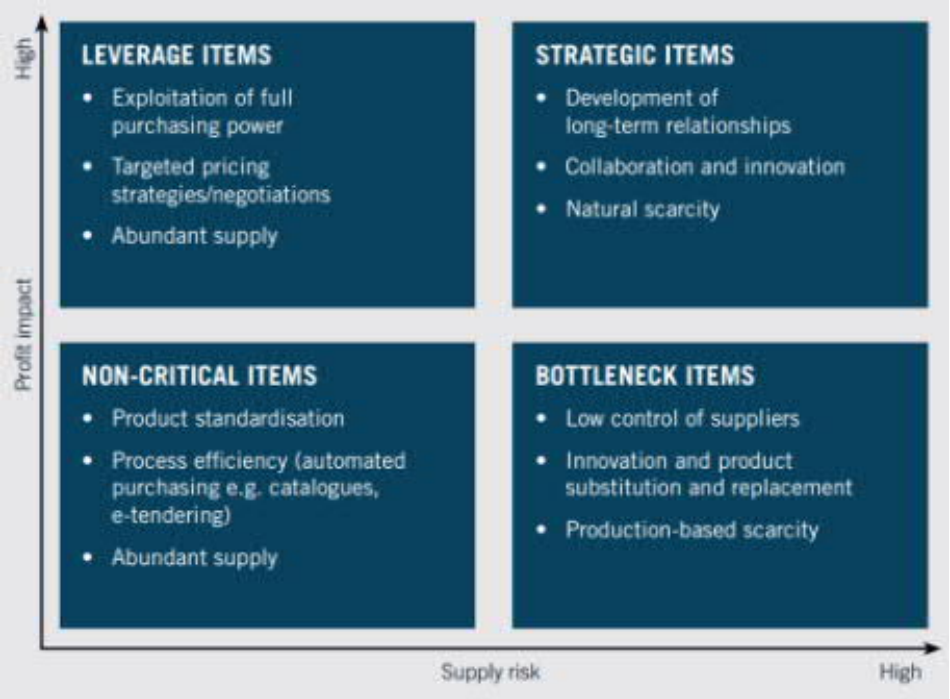

Figure 9. Peter Kraljic's Matrix (Webb, 2017.)

However, general procurement process consists of three main phases which are preparation of a procurement, making a procurement decision, and controlling and monitoring of a procurement (Junnonen and Kankainen, 2012, pages 44-45). Figure 10 present an example of general procurement process of an individual procurement and describes the actions related to these three main phases.

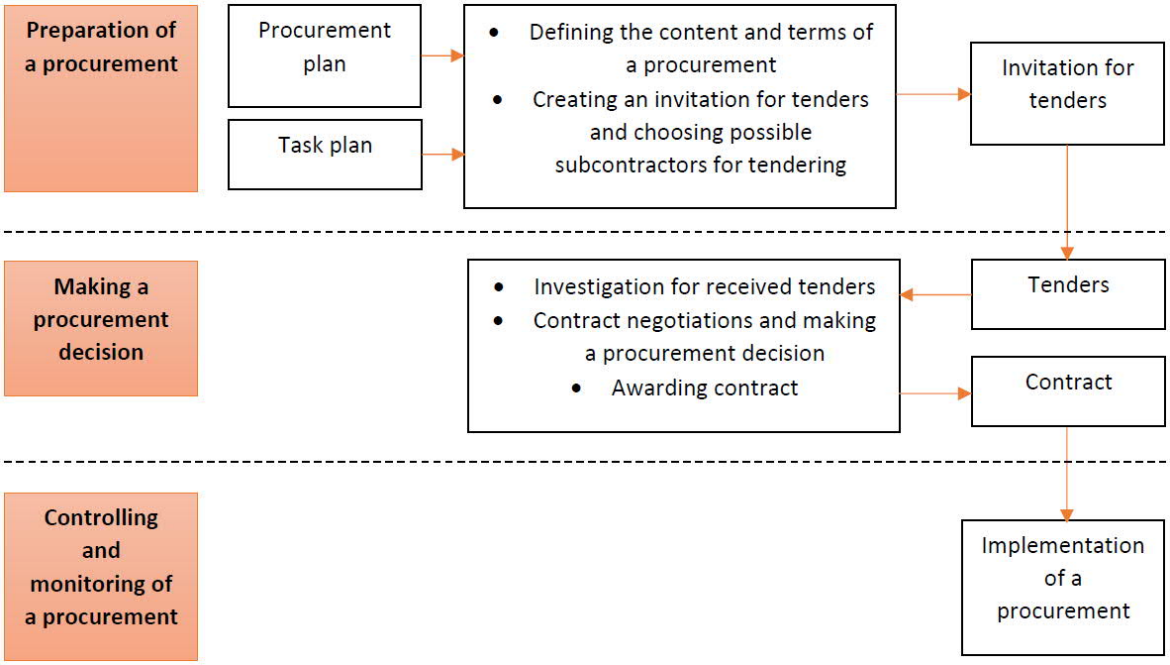

Figure 10. An example of general procurement process (Customized based on reference: Junnonen and Kankainen, 2012, page 45.)

2.5.2.1 Procurement strategy and plan

A procurement strategy is a longer-term plan to provide guidelines for action and thus support practical procurement. The most important stakeholders must be involved in the strategy preparation. Procurement is a hub for one's own organization and external supplier network, thus the influence area of the procurement activity is much wider than mere procurement. The procurement perspective should also be considered in the company's other activities and reciprocally the objectives of other activities must be taken into account when creating the procurement strategy. Generally, one must consider how long is the timespan for the procurement strategy in question when creating it and how detailed it is created. The procurement strategy should take position on key strategic choices. (Anttila, Jussila & Mikkola, 2013, page 11.) Procurement strategy can be divided into three different levels which are procurement strategies based on competitiveness (highest level), procurement strategies related to procurement procedures (middle level) and procurement strategies based on performance (lowest level). Usually procurement decisions that have influence on company's competitiveness and position at market are made at highest level of organization. The purpose is to improve company's competitiveness by decreasing long-term procurement costs. Procurement strategies related to procurement procedures are meant to coordinate organization's internal units and build up supplier network for organization. These middle level strategies concentrate on choosing trade contractors and suppliers, length of contracts, centralizing or decentralizing procurements and actual costs of procurement department. Procurement strategies based on performance concentrate primarily on managing procurement resources, monitoring procurement costs and creating value for the customer at the lowest level of organization hierarchy. (Junnonen and Kankainen, 2012, pages 14-15.)

Company's procurement strategy creates guidelines for project-specific procurement strategy. Project-specific strategy comprehends forming distribution of procurements, timing

procurements and selection of formats for procurements. Project-specific operating principles are affected by the project delivery method, readiness levels of designs, schedule tension and competition situation in the market. Procurement tasks can be organized so that there is separate procurement department which handles all procurements for every construction site, or every procurement is handled at construction site. Usually procurement department consist of procurement manager and procurement engineers who procure and purchase work, services and materials for construction projects. In typical construction projects, procurement department is involved in even a little larger project-specific procurements. (Junnonen and Kankainen, 2012, page 15.) Nevertheless, company's general procurement strategies often have a high degree of uncertainty and prediction can be hard when generating a strategy. Framework and market conditions may develop in a different direction than assumed during creating the strategy, thus procurement strategies must be flexible and able to be adapted to changing market conditions at regular timespans. (Weigel and Ruecker, 2017, page 10.)

Procurement planning is a part of projects production management, and project's economical targets are presented at target budget. The ways how production can be managed according to the target budget are presented in the general schedule and procurement plan. Project's production planning cannot be completed at a time in the whole extent at satisfactory level, thus it must be decentralized into parts which are production planning of the entirety and planning of the individual tasks. In the same way, procurement planning must be seen as a chain which proceeds systematic through the whole project's lead time. Due to this, procurement planning is decentralized into three main phases which are planning of tender phase procurement, planning of implementation phase procurement and planning of individual procurement. Procurement planning of tender and implementation phase is part of the entire project's production management and is used to ensure that production fulfills the set targets. Whereas, planning of individual procurement is used to ensure that individual procurement doesn't fail and thus jeopardize the planned implementation of the entire project. (Junnonen and Kankainen, 2012, page 24.)

In the planning of tender phase procurement, planning is based on invitation for tenders' documents, company's procurement policy and created basic production solution for the project which contains decisions about distribution of building's sections, order of tasks and sections in implementation and construction time. In tender phase, the preliminary distribution of procurements is defined which means that the contracting entities are formed. Economically and time critical procurements are identified, and also urgent procurements. Principle solutions are planned which relate to construction site's logistics. The milestones and contract terms, set by the owner's construction management, must be taken into account when planning procurements. Planning of tender phase procurement is focused at both procuring advance tenders and searching different options. Advance tenders may be binding or non-binding. (Junnonen and Kankainen, 2012, pages 25-27.)

In the planning of implementation phase procurement, contract documents, general schedule, target budget, and project's quality plan work as initial data for general procurement planning. With schedule and target budget, the limits for procurement entities are defined, and conditions for awarding contracts and controlling procurements are created. Procurement plan is created based on general schedule and its central purpose is to form procurement catalogue, ergo, form procurement entities which can be called as procurement packages, and procurement schedule. The cost targets are derived from the target budget as well as the

times of need and subcontract's construction time are derived from the general schedule for procurement packages. Procurement plan works also as a guide for design management to schedule delivery of designs. Procurement catalogue presents procurement entities which are individual trade contractor specific subcontracts and material procurements. The purpose of procurement schedule is to schedule actions related to the procurement so that the implementation of the general schedule is secured. (Junnonen and Kankainen, 2012, pages 28-30.) Figure 11 presents different levels of procurement planning.

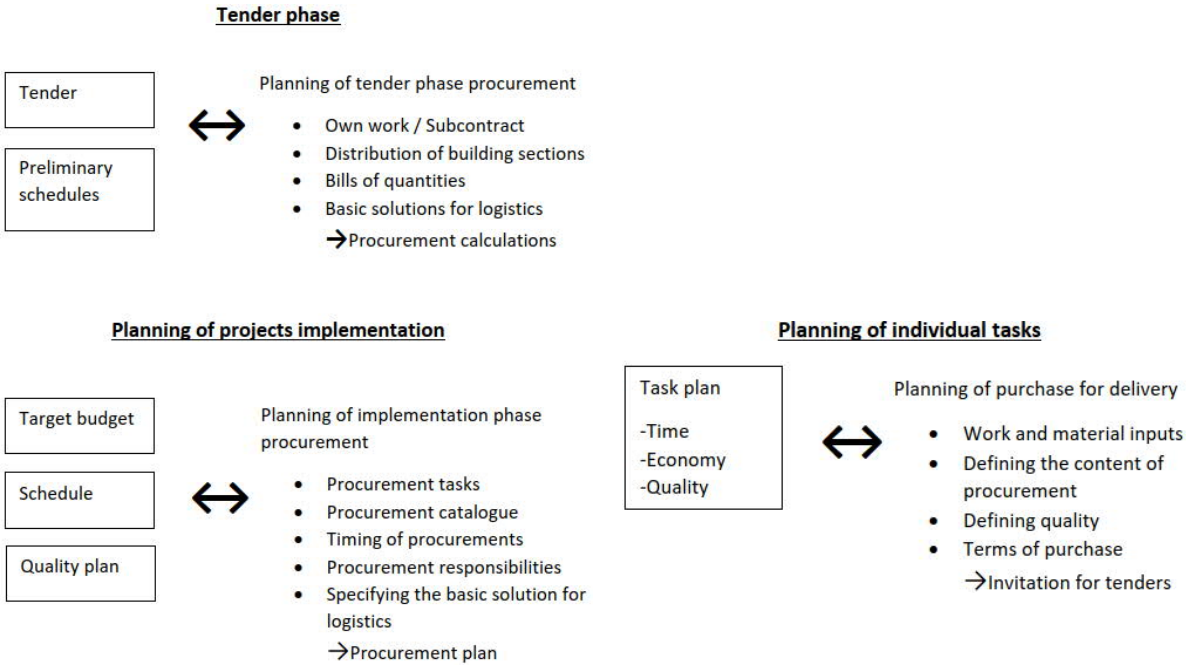

Figure 11. Different levels of procurement planning (Customized based on reference: Junnonen and Kankainen, 2012, page 25.)

The project-specific procurement schedule is used to schedule individual procurement packages and critical procurements which have huge impact on costs or long delivery times. Needed delivery times for plans, times for sending invitations for tenders, deadlines for tenders, order times and delivery times are recorded in procurement schedule. Needed delivery times for plans are important in the point of view of procurement because without proper plans it is hard to make proper and accurate procurements and that way procurement schedule has a connection with the design schedule. (Junnonen and Kankainen, 2012, page 34.)

Without proper plans subcontractors cannot give accurate tenders for prime contractor which will lead to increase of costs because they have taken into account the risk in their prices, and when plans are supplemented by the designers during construction also new unit prices will appear. This means usually additional and alteration works in the point of view of subcontractors and prime contractor, but sometimes it is very difficult for the owner to understand why the prices are suddenly increasing just because of few new designs in the plans. Usually additional and alteration works lead to tough negotiations between the owner and prime contractor as well as between prime contractor and subcontractors, and require unnecessary time and all this time spend into these negotiations is out of the smooth running of the project. One cannot make additional work for free which was not brought out during awarding a contract, but one cannot either make all decisions too early from the point of view of the owner. Construction manager must inform and help the owner to make decisions

in time for the designers and prime contractor to prevent these kinds of unnecessary situations. Therefore, it would be better to tackle these problems already earlier and create procurement plan and design schedule properly so that prime contractor and design management presents needed delivery times for plans and the owner makes decisions in the time with help of construction manager.

2.5.2.2 Subcontract process

Outsourcing construction tasks and work to subcontractors or suppliers is a general practice in the construction industry. There is often a need for specific skills or certain technology and materials in projects, thus the involvement of subcontractors and suppliers is necessary. (Rostiyanti, Hansen & Ponda, 2020.) Especially, in competition and business premises construction where projects are more complex and unique. Subcontracts are separated contracts from the prime contract and subcontractors work for prime contractor (Rostiyanti, Hansen & Ponda, 2020). Prime contractors need to emphasize and improve collaboration and teamwork among project parties to achieve better performance (Demirkesen and Bayhan, 2019).

Subcontracts are procurements which include installation works and often also materials for work. Subcontracts are awarded with contracts and usually YSE 1998 is used as terms of contract. According to general conditions for building contracts, prime contractor acts as owner or customer and subcontractor acts as contractor. Special attention must be paid to the contract itself and contract process because in Finland there is no legislation regulating works contracts. The contract is valid based on tender and accepting response in Finland. All contracts should be made in writing, although the oral agreement is valid as well. The costs of subcontract can be influenced mainly before the contract is signed and terms considering timing and quality are defined and created when awarding the contract. After awarding the contract, the subcontractor may be influenced only to the extent permitted by the contract. (Junnonen Juha-Matti and Kankainen Jouko, 2012, pages 8-9.) As agreements between prime contractors and material suppliers are transactional and routine, prime contractor and subcontractor relationships require continuous or occasional cooperation among different levels in the construction and subcontracting organizations. Construction industry has developed so that today the prime contractor often acts as construction manager who coordinates and administers the construction project and doesn't perform the work itself as in the past. The actual work is done by subcontractors who are specialized into some area of construction industry. Experienced subcontractors are crucial links in the construction supply chain and most adaptable subcontractors are usually searched by prime contractors. (Benton and McHenry, 2010, pages 77-78.)

There are different contract types available for use when awarding subcontracts and the choice of contract type is usually closely related to the magnitude of risk associated with the specific work at construction site. Subcontractor's risks include often increases in materials and labor, but to estimate the technical risk, the complexity of the specific work, the scope of work, the accuracy of design specifications and experience about similar works must be analyzed. When data and information about work methods, productivity rates, scope of work and design specifications becomes more defined and predictable, technical risks are decreased. (Benton and McHenry, 2010, pages 88-90.) However, there are for example five

different contract types available such as Lump Sum/Fixed price contracts, Unit Price contracts, Cost-Plus contracts (Antoniou & al., 2012), Design-Build contracts and Negotiated contracts (Benton and McHenry, 2010, pages 90-93).

Junnonen and Kankainen (2012, page 9) have presented subcontract process which can be seen in the Figure 12. The process contains different steps until the contract has been awarded. All steps are important in the process but creating invitation for tenders, comparison of tenders and contract negotiations must be highlighted in the process, and these all have an effect on awarding contract.

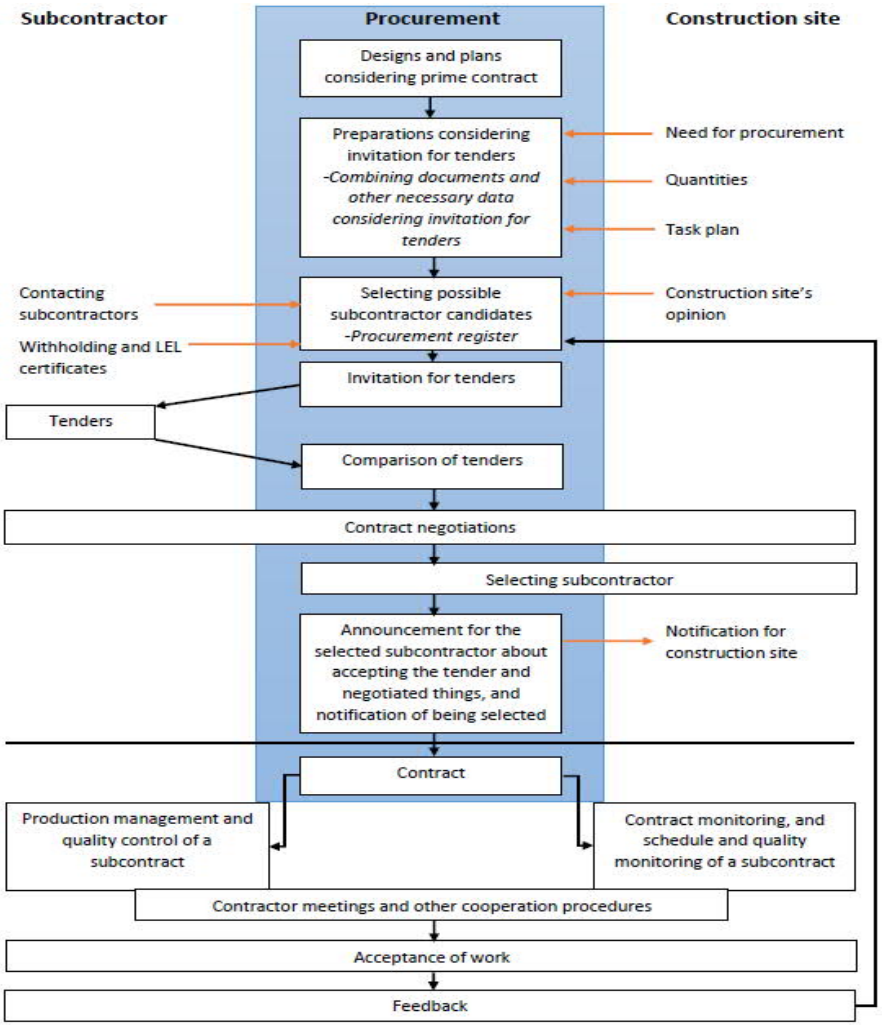

Figure 12. Subcontract process (Customized based on reference: Junnonen and Kankainen, 2012, page 9.)

Before starting to compile the invitation for tenders, the prime contractor must have made proper procurement plan and have a comprehensive understanding of the project specifications. The most important documents in invitation for tenders are written specifications and construction designs and plans. When compiling invitation for tenders, one should take into account the opinions from construction manager, cost estimating manager, project manager and legal counsel in order to have all necessary aspects in invitation for tenders. (Benton and McHenry, 2010, pages 80-81.) In order to receive unambiguous tenders, a carefully drafted invitation for tenders is required. The invitation for tenders documents must contain all necessary information which may influence the tenderer's tender price. In particular, the subcontractor must be informed of matters for which the information provided is still incomplete

and uncertain at the tender stage. Invitation for tenders documents form the basis of the actual subcontract. (Junnonen and Kankainen, 2012, page 54.)

Construction subcontract negotiations are business activity and rational choices should be considered more than other factors that have influence on the decisions of the negotiating parties. Decisions should be made rationally based on strategic choices, expected values and calculations. A win-win result, where both parties achieve some of their objectives, can be achieved by knowing the needs of the other party. Revelation of the needs by negotiating parties can lead to achievement of higher gain for both parties. Nevertheless, transparency doesn't mean that company's commercial secrets would be disclosed. (Anysz, 2019.) Contract negotiations are based on the comparison of tenders when the most competitive subcontractor candidates are selected. The decision about selecting subcontractor shall take into account the selection criteria indicated in the invitation for tenders, the overall economy, the deviations from the invitation for tenders and possible options. (Junnonen and Kankainen, 2012, page 59.) It must be decided whether to emphasize the scope, quality or cost point of view when awarding an individual subcontract. Usually, the prime construction contract steers the targets related to subcontracts.

The purpose of subcontract negotiations is to ensure the best possible outcome in terms of objectives, both financially and in terms of the content of the tender. It is also necessary to ensure that both parties have a common understanding of the responsibilities and obligations of the contract. The key issues are reviewed, and the content of the contract is clarified by missing issues. The designs and plans are inspected often during the negotiations and their completeness is assessed from the point of view of construction site production. Subcontract negotiations record document will become usually an important part of the subcontract itself. (Junnonen and Kankainen, 2012, page 61.) The content of subcontract is based on the invitation for tenders documents, the tender, subcontract negotiations record document and other agreed matters and terms. The final outcome is divided into a contract form and supplementary annexes which contain commercial and technical documents. (Junnonen and Kankainen, 2012, pages 66-67.)

2.5.3 Procurement and detailed design phase in SUKE-model

In detailed design phase, procurement strategy and distribution of procurements is formed. Project management strives to achieve the targets defined by the owner with procurement strategy which is a part of project plan. Procurement strategy consists of distribution of procurements and their timing as well as selection of procurement formats which are presented further in the text. The features of the project, schedule tightness and competition in the markets have influence in the procurement strategy. Good example can be timing of the decisions related to infill spaces when there are rental contracts existing. Another example can be the number of available trade contractors and their capacity. (Kruus & al., 2006, page 37.) Procurements are distributed into different procurement packages and they are utilized for the design packages. It should be remembered that the owner retains the decision-making power in every procurement.

In CMR delivery methods, having construction work done is based on distribution of procurements. The decisions of the owner as well as cost and schedule planning work as a base for distribution of the procurements. Thus, distribution of procurements is based on getting

necessary decisions and plans, fields of construction industry, location and time. Basic model for distribution of procurements is professional fields and fields of construction industry which provide products and services into the markets. Professional subcontractors can propose different options for implementation with the cost effect. The distribution of different locations can also act as a tool for distribution of procurements because procurement department can procure different subcontractors, from the same professional field, for working in different locations of the building if needed. With this, owner and prime contractor can decrease their dependence from singular subcontractors. Delivery of the plans from designers and proceeding of the construction must be taken into account in the distribution of procurements. Distribution will be made according to construction phases with categorizing foundations, frame of the building, facades, transforming infill structures and area works. With this, in the same field of construction industry, like for example metal works or masonry, there can be several invitations for tenders and deliveries. It is extremely important to categorize transforming infill parts from the fixed support parts of the building. (Kruus & al., 2006, page 38.)

SUKE-model defines three different procurement formats, from the point of view of designing, in the following way:

1. Procurement performed with detailed designs.
2. Procurement performed with normative designs.
3. Procurement performed with design requirements.

(Customized based on reference: Kruus & al., 2006, page 38.)

In the procurement performed with detailed designs format, invitation for tenders includes all detailed designs about the concerned subcontract and there must be no significant lacking designs. Design management is responsible for ensuring that designs meet their targets and decisions for being able to design are made in time. Design solutions must be so kind of that several different subcontractors are able to implement them into real structures. With this kind of procurement format, fixed-price and unit price contracts are possible options. Unit price is usually utilized when exact quantities of products and locations are not known. The amount of additional and alteration works will be minor. (Kruus & al., 2006, pages 38-39.)

In the procurement performed with normative designs, tenders are requested with preliminary designs and designs can be supplemented during the waiting period for cost estimations and offers calculated by subcontractor candidates. Designs can be also developed in negotiations based on subcontractors' proposals. Collaboration between parties is important in detailed design and final detailed designs will be attached to final subcontract. The advantage of this procurement format is that invitations for tenders can be send earlier and faster. (Kruus & al., 2006, page 39.) In the same time, procurement department gets information about different subcontractors' willingness to make tenders and can react earlier if there are some kind of difficulties regarding to it. (Kruus & al., 2006.)

In the procurement performed with design requirements, tenders are requested with functional and aesthetic requirements. The purpose of this procurement format is that subcontractor takes responsibility for detailed design and complete delivery and installation of the product with technical solutions, and subcontractor commits early to the lump sum and delivery schedule. The owner can utilize innovations provided by subcontractors and subcontractor is responsible for designing the connections to earlier structures designed by owner's

designers. Subcontractor is also responsible for the functionality of the designed solutions and the final content of procurement, including especially structural connections and implementation of supplementing detailed design, is specified in procurement negotiations. Designs of production subassembly contract must be checked, agreed and coordinated by the owner's designers. This kind of procurement format increases the number of required tender negotiations. (Kruus & al., 2006, page 39.)

Even though procurement package is one entity to be procured, it can require several different plans from different fields of designing. Also, the procurement format of procurement package has an effect on what kind of plans and what kind of level of detail information procurement package needs to be procured, or invitation for tenders needs to be send. Because of this, procurement strategy/plan and distribution of procurements are needed for design management to be able to create suitable design schedule and packages.

2.6 Supply chain process versus project process

As the emphasis is on modeling volume production in the manufacturing supply chain management, construction supply chain management concentrates on the coordination of separate quantities of materials and related special engineering services delivered to unique construction projects. The importance of supply chain process and its management is increasing because global sourcing of assemblies and materials as well as shortage of craft labor force into increasing some amounts of value-added work to be produced deep in the supply chain off-construction site. Also, faster and more responsive construction processes are demanded by owners, thus closer coordination between the prime contractor and the owner as well as more responsive production chains are needed. (O'Brien & al., 2008, chapter 1, page 1.)

Benton and McHenry (2010, page 49) describe that *"The supply chain process is based on the idea of efficient resource coordination and teamwork"*. When prime contractor has to deliver a high-quality project under budget in time and takes full responsibility for managing and coordinating the supply chain, the supply chain management approach depends on the different principles. One must compete by eliminating waste and adding supply chain value. Long-term relationships should be established with subcontractors and suppliers as well as the focus must be on supply chain value analysis and target costing. Continuous improvement through the supply chain must be developed and upstream and downstream information technology should be promoted. However, it is essential to maintain strong relationships with best subcontractors and suppliers when there is a major trend toward contractor specialization to more subcontracting of variety of works. Competitive advantages can be gained through supply chain management and managing subcontractor and supplier relationships. (Benton and McHenry, 2010, pages 50-51.) Strategic supplier relationships in the supply chain requires that the prime contractor must ensure that the relationships are properly managed. One way to manage relationships is to compile supplier profiles for each strategic source which include company overview, key management contacts, SWOT-analysis, information about current contracts, relationship within the firm and financial information. With proper management, competitive advantages can be gained. (Benton and McHenry, 2010, pages 54-59.)

Christopher (2011) has defined the supply chain as *"the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer"*. Most organizations have traditionally viewed themselves as entities that exist independently from other organizations and competed with the others in order to survive. Nevertheless, nowadays organizations are increasingly focusing only on their core business that they do well and have advantage in the market. This leads to increasing use of subcontractors and other trade contractors. When the supply chain begins to form like this, each of these organizations in the chain are dependent upon each other. Some companies seek profit improvement or cost reduction at the expense of their supply chain partners but they don't realize that transferring costs upstream or downstream does not make them any more competitive because ultimately all costs will be reflected in the price paid by the customer or the owner. The purpose is to achieve the state that the supply chain is more competitive through the value it adds and the costs that it reduces considering the overall costs. (Christopher, 2011, pages 13-15.) There are different steps defined for achieving an integrated supply chain shown in the Figure 13 which describes well the development that has to be made in order to achieve proper supply chain.

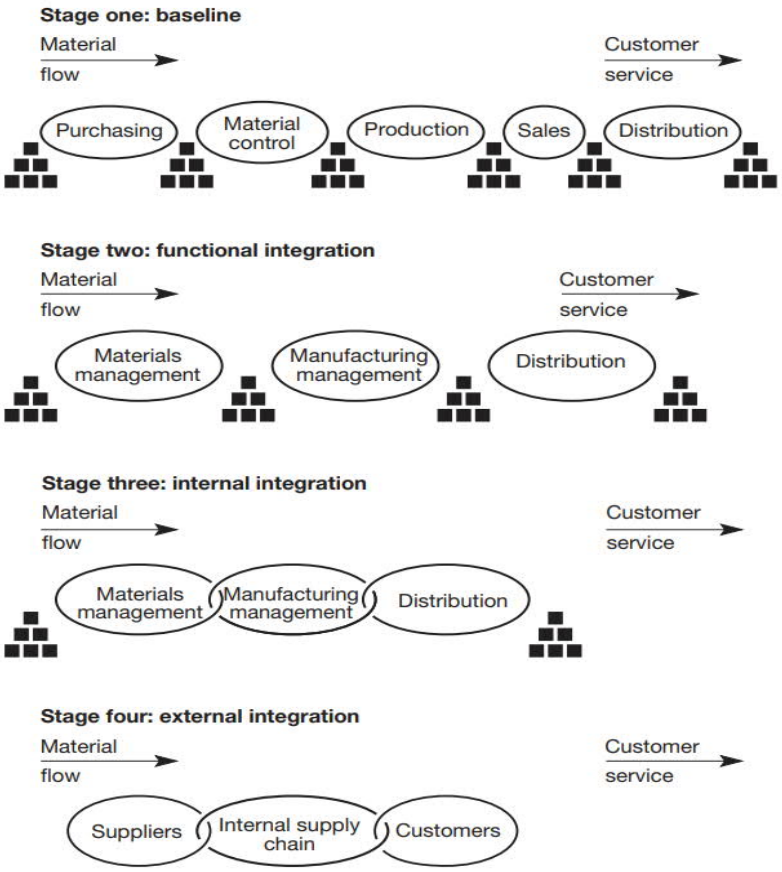

Figure 13. Achieving an integrated supply chain (Christopher, 2011, page 14.); (Stevens, 1989.)

The supply chain can have many sources which cause complexity into the entirety. The amount of links and nodes in a network increases the complexity of supply chain because the more there is these links and nodes the more complex the supply chain becomes. Companies are dependent on external suppliers and subcontractors who are also dependent upon a web of second level suppliers and so on in the supply chain. There is the possibility that many second or third level suppliers feed a focal company's upstream supply chain so that

the focal company is not aware of this happening. Extended networks increase the potential for unexpected disruptions to the supply chain. There are innumerable processes behind every supply chain which are divided into company's internal processes and processes managed by upstream and downstream partners. When there is too much different activities, non-parallel multiple steps and non-value adding activities, the supply chain becomes complex. The processes must be constantly reviewed, developed and re-engineered in order to decrease the process complexity and at the same time the supply chain complexity. The supply chain is also affected by the range of products and services that are offered to the market. The more variants and brand extensions are made of products and services, the more complex the supply chain becomes. The design of the products can have a huge impact on the complexity of the supply chain because decisions on the choice of materials and components can affect directly or indirectly to total life cycle costs and both agility and responsiveness. Product complexity can be a result from high number of components or subassemblies. It must be mentioned also that product design decisions can have so kind of impacts that if materials or components are specified which happen to have lengthy replenishment lead times then the ability to respond rapidly to changes in demand for the product will be impeded. Logistics and supply chain planners should be involved early in the design process in order to avoid later complexity. (Christopher, 2011, pages 161-163.)

Customer complexity causes complexity as well into the supply chain. Each customer has their own demands considering their ordering patterns like for example size of orders, frequency of orders and delivery requirements. Products, services and solutions are customized and non-standardized which affect complexity into the supply chain and the problem is that companies have usually a limited understanding of the true costs of servicing individual customers. The size of the supplier base can have an effect in the supply chain complexity. The higher the number of relationships that must be managed is, the more complex the supply chain is and increases total transaction costs. It is good to develop collaborative working with key suppliers but new innovations and quality or profit improvements cannot be achieved without developing new opportunities with new suppliers. Because of this it is important for companies to manage actively the supply chain and avoid too high level of dependence and identify opportunities and risks. Organizational complexity can cause also complexity into supply chain. As the companies' businesses have organized around departments and functions and their organization charts have many levels with hierarchical structures, they tend to focus on efficiency rather than customer facing with a focus on effectiveness. The problem is that functions often have proclivity to become silos with their own agendas and the purpose of the business to win and maintain profitable customers can disappear. These silos must be broken, and organization must be re-shaped around the key value-creating and value-delivery processes. These kinds of process-oriented businesses should be cross-functional and emphasize improvement on teams and process in terms of speed and reliability. Waste and non-value adding activities must be removed and constant re-engineering of processes must be implemented to reduce the supply chain complexity. All earlier mentioned sources, which can cause complexity into the supply chain, forms together the information complexity which must be managed by reduction in the other sources as well as greater visibility. (Christopher, 2011, pages 163-165.)

Christopher (2011) highlights that *"often a significant source of supply chain complexity is the actual design of the product itself"* which is important to recognize. A large part of total through-life costs is determined at the design stage and there are multiple ways how design decisions can impact later supply chain complexity and costs. For example, manufacturing

complexity can be increased as well as flexibility and responsiveness reduced by the decisions on the functionality of products. Lack of commonality increases complexity, as the bill of materials is impacted by the decisions on product design, complexity will be added by low levels of component commonality. Some design decisions will determine the choice of supplier and that way could impact replenishment lead time. Also, the chance of supply chain disruption could be potentially increased if the design decision involves unreliable supply sources. The design of the product will have implications for inventory levels, for those products which need after sales support like service parts. Product design decisions enhances or constraints the ability to postpone the final configuration or the packaging of a product. (Christopher, 2011, pages 166-167.)

One point of view to examine the supply chain process in construction is to divide the entity into project process and supply chain as presented in the Figure 14 below. In this point of view, the process related to the construction project contains program, design, planning, production and warranty and reparation phases. The process and development flows through the project phases. While the supply chain includes manufacturer, reseller, contractor and facilities management in the chain and the value creating flows through the different parties. (Peltokorpi, 2018, lecture 1.) When examining the supply chain process, one must define from which perspective the supply chain is examined and what aspect the supply chain considers because there are different point of views and supply chains existing. Is the supply chain considering about materials, products, subcontracts, project or designs etc.? However, the supply chain parties or phases create value for the next party or phase and in the end the created value reaches the ultimate customer. There are also existing external and internal supply chains. External supply chain considers different companies or parties involved which are acting as individual organizations and are dependent from each other in the chain. Internal supply chain considers company's or organization's different internal departments or units involved which are acting as parties of the chain to create value for the next party and that way are dependent on each other.

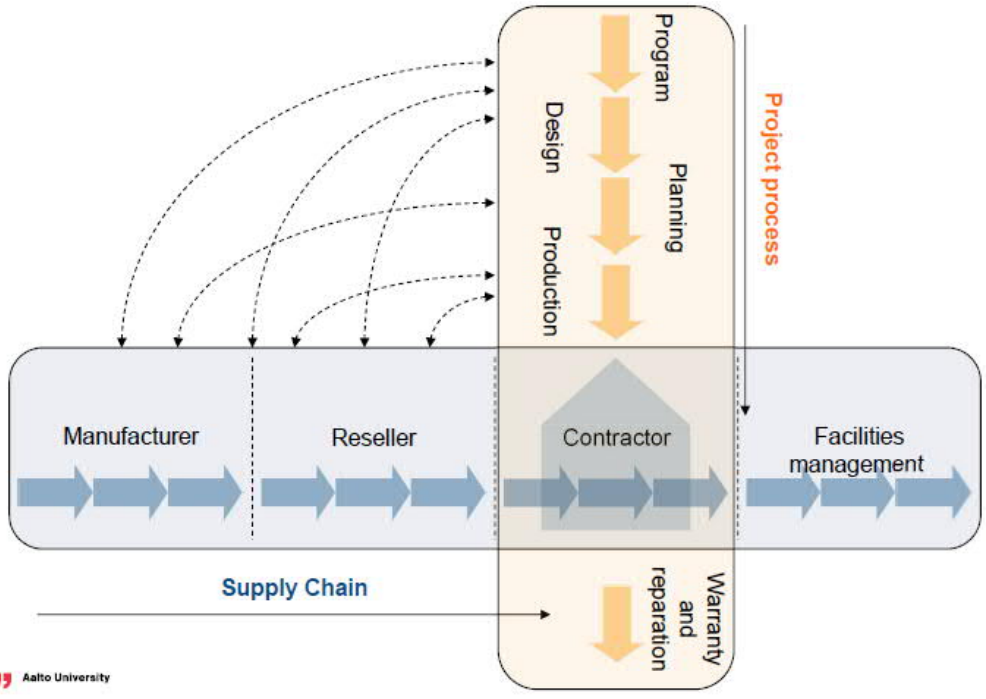

Figure 14. Project process versus supply chain (Peltokorpi, 2018, lecture 1.)

2.6.1 Supply chain management

Mentzer & al. (2001, page 18) defines the supply chain management as *"the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole"*. There is also another description for the supply chain management as it *"refers to managing the flows of physical products and services, information, and money between the activities or process steps that companies perform, while aiming for customer service as the goal"* (O'Brien & al., 2008, chapter 6, page 2). Mentzer & al.'s description of supply chain management represents traditional business and in the Figure 15 below they have developed a conceptual model illustrating supply chain management entity. The supply chain is illustrated as pipeline which shows directional supply chain flows, and traditional business functions manage and accomplish these flows from the supplier's suppliers through the customer's customers to ultimately provide value and satisfy customer. The role of customer value and satisfaction is critical to achieve competitive advantage and profitability for the entire supply chain and individual companies. (Mentzer & al., 2001, page 18.)

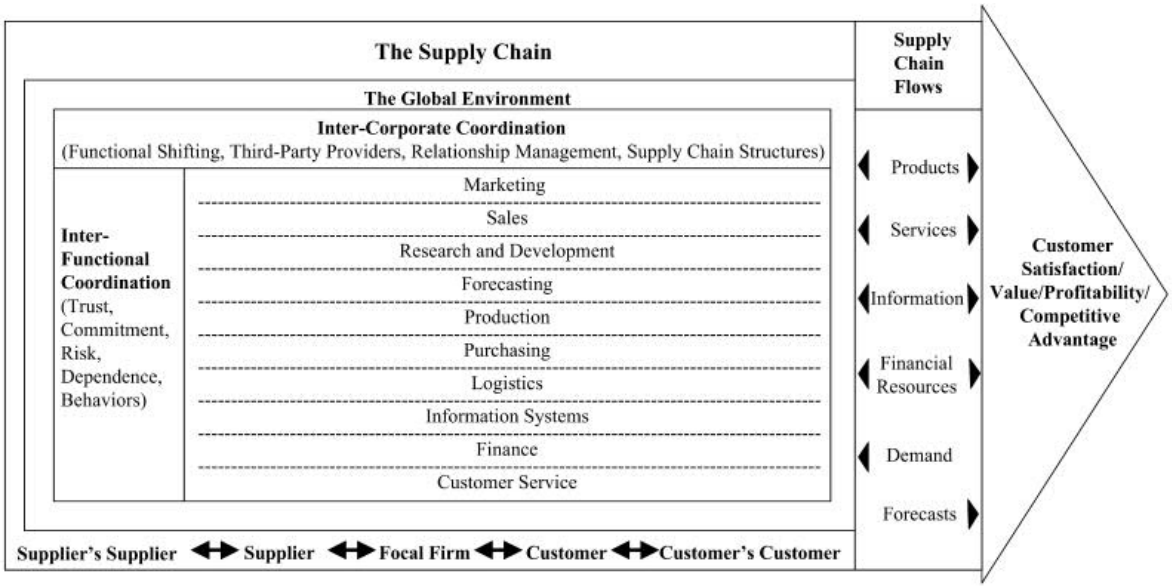

Figure 15. A model of supply chain management **(***Mentzer & al., 2001, page 19.)*

The profitability can be increased by construction supply chain management decreasing delays in delivery of services, materials and equipment to the project site. The implementation of construction supply chain is the process of contracting with subcontractors, purchasing materials and buying or leasing equipment in order to produce completed project. The central focus of supply chain implementation is construction purchasing which is responsible for sustainability and efficiency of project. Implementation of the supply chain is supplemented by the supply chain information model where project requirements are defined by the owner. The expectations about the project are communicated downstream. A series of information, material and money flows originate from owner's requirements and the quality of these flows defines the level of supply chain integration. There could be fewer disruptions if various processes were more integrated and information sharing would drive them. Construction

supply chain improvement sources can be effective supply chain practice and effective information sharing, thus both of them have to be developed. (Benton and McHenry, 2010, pages 128-130.)

Practices related to construction supply chain planning are used to process information from the construction project's owners, designers, construction managers, suppliers and subcontractors. The planning is driven by developing well estimates of project requirements and coordinating various project activities upstream and downstream. Coordination and interaction within the project supply chain is important and coordination with subcontractors and materials suppliers is critical for completing high-quality projects on time and under budget. From this we can come to that construction supply chain management is based on coordination of information, materials and money flows between different project partners, and by integrating these flows we can increase the likelihood for a successful project. (Benton and McHenry, 2010, pages 130-131.)

Lean thinking has been adopted by many companies in the automotive and other manufacturing sectors, and it is heavily influenced by the Toyota Production System. One purpose of it has been to try to improve supply chain performance. (Erikson, 2010.); (Womack & al., 1990.) (Towill & al., 2000; Wee and Wu, 2009.) (Naylor & al., 1999; Segerstedt, 1999.) Construction industry has also recently adopted lean thinking for supply chain improvement practices (Erikson, 2010); (Ballard and Howell, 2003; Green and May, 2005; Jorgensen and Emmitt, 2009). The core elements of lean construction are waste reduction, process focus in production planning and control, end customer focus, continuous improvements, cooperative relationships and systems perspective. When improving construction company's practices related to the supply chain management, three stages of lean construction could be considered. First lean stage focuses on waste elimination from operational and technical perspective and its essential parts are cutting out unnecessary costs, elimination of needles movements, optimizing workflow and sharing the benefits from improved performance. The managers are responsible and in center of this. The second lean stage focuses on enhancing cooperative relationships, eliminating adversarial relationships and teamwork among supply chain actors, and its essential parts are cooperation, long-term framework agreements, workshops and facilitator. The third lean stage involves structural change of project governance and its essential parts are information technology, pre-fabrication, Last Planner, a rethink of design and construction, bottom-up activities and emphasis on individuals, long-term contracts, decreased competitive forces, training at all staff levels and a systems perspective of both processes and the product. (Erikson, 2010.); (Green and May, 2005.)

Vrijhoef and Koskela (2000) have introduced the four roles of supply chain management in construction. The first role is improving the interface between site activities and the supply chain. The focus should be on improving the total flow of material and cooperation between suppliers and contractors. The second role is improving the supply chain. It focuses on development of specific supply chains, and in-depth cost and time analyses are important for identifying potential improvement and for developing supply chains. (Vrijhoef and Koskela, 2000.); (Wegelius-Lehtonen & al., 1996.) Uncertainty in the supply chain, varying capacity conditions and varying site conditions are factors that can decrease the performance of supply chain and productivity (Vrijhoef and Koskela, 2000); (O'Brien, 1995, 1998). The third role is transferring activities from the site to the supply chain. The purpose is to be able to redesign the supply chain so that some on-site activities can be transferred off site. Good example can be prefabrication which can be regarded as a structural means for eliminating

on-site activities from the total production chain, thus one must concentrate on the design of the supply chain. (Vrijhoef and Koskela, 2000.); (Warszaswki, 1990.) (Sarja, 1998.) The fourth role is integration of site and supply chain. Alternative means for integrated management of the supply chain and the construction site can be open building concept (Vrijhoef and Koskela, 2000.); (Van Randen, 1990) and sequential procedure concept (Vrijhoef and Koskela, 2000.); (Bobroff and Campagnac, 1987). The benefit of open building concept is that decisions of users regarding the interior of the building can be postponed by separating the infill from the structure, from point of view of production. Also, when users' needs change during the lifecycle of the building, open building concept provides adaptability so that users can reconfigure the space. The purpose of the sequential procedure concept is that the site work is structured as successive realizations of autonomous sequences. The target of these concepts is to replace construction's usual temporary chains with permanent supply chains. (Vrijhoef and Koskela, 2000.)

Stevens and Johnson (2016) have constructed a supply chain operating model dynamics of change shown in the Figure 16 and it includes supply chain improvement model. The supply chain improvement is first divided into two parts. Process and capability improvement part contains tools, techniques, resources, capability and approach. Structural adjustment part contains linkages, tiers, relationships, reach, governance and transmissivity. Process and capability improvement part involves different steps like performance profile, supply chain capability and supply chain performance, and everything is connected to performance cycle of change. Whereas, structural adjustment part involves steps like risk profile, including aspects like complexity, uncertainty and instability, and supply chain risk, and everything is connected to risk cycle of change. (Stevens and Johnson, 2016, page 12.)

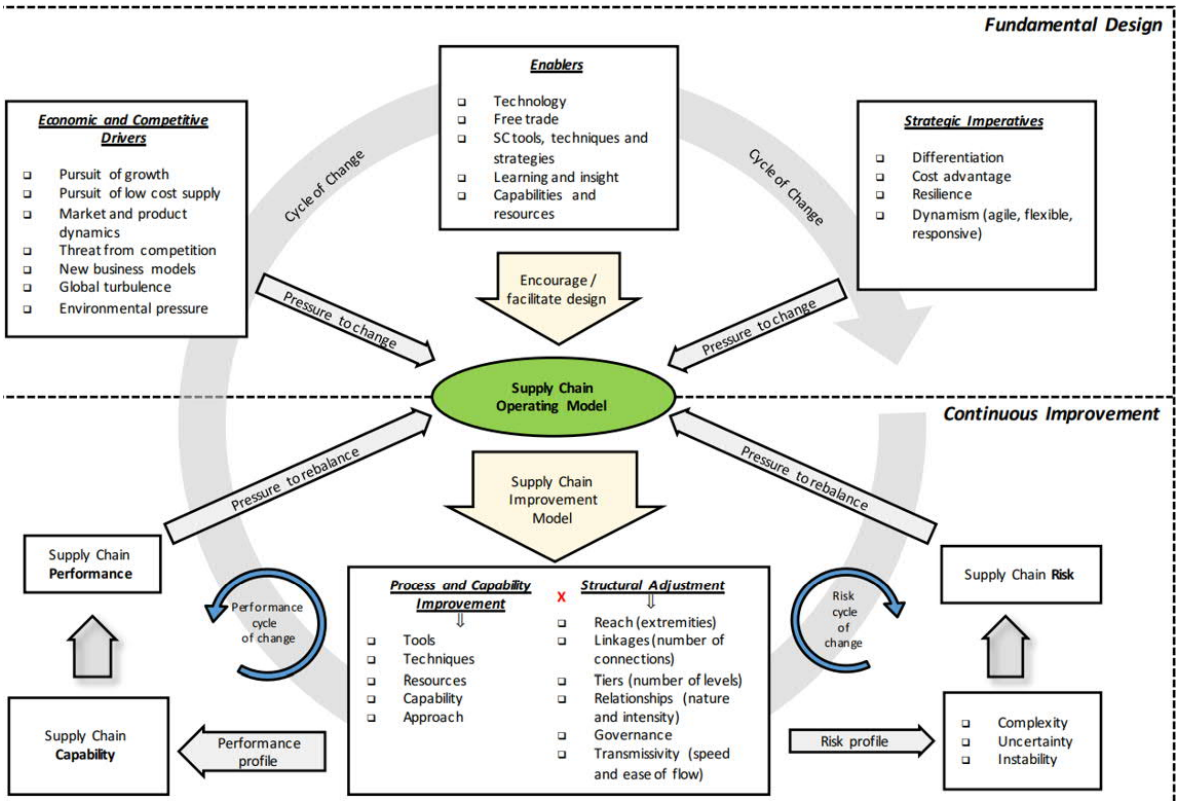

Figure 16. Supply chain operating model dynamics of change (Stevens and Johnson, 2016, page 12.)

Process analysis supports the process improvement because it breaks the process down into its component parts by mapping information and product flows, in an attempt to improve understanding and expose opportunities to improve (Stevens and Johnson, 2016, page 12.); (Hines and Rich, 1997). The performance of supply chain is based on the interaction of processes and supply chain are naturally complex, thus developing a supply chain's performance requires concentration on the interaction of processes instead of optimization of isolated processes (Stevens and Johnson, 2016, pages 12-13).

Supply chain management can have barriers that prevent implementing and improving the supply chain properly. Benton and McHenry (2010, page 14) state that *"Intense implementation challenges, however, often prevent effective exploitation of supply chain management benefits and prove detrimental to any planned operational efficiency advantage"*. The history of individualistic and adversarial construction industry complicates the attempts to create involved cooperative relationships with other constructing-related entities. The fear of losing control makes most construction companies uncomfortable when supply chain management necessitates sharing of traditionally proprietary information, planning, goals and strategy. Also, companies have to create a high level of awareness both themselves and their partners which is required when implementing interfirm collaboration, and it can be difficult to perform. One barrier can also be that usually supply chain members tend to focus on individual goals instead of mutual goals. Lack of understanding of supply chain and project owner are often likewise barriers to tackle. The possible benefits of succeeding in the improving the supply chain can be for example improved project quality, work methods, completion times and decreased costs. (Benton and McHenry, 2010, pages 14-16.)

2.6.2 Construction company's internal supply chain process

This Master's thesis considers prime contractor's internal supply chain process which is however connected to external supplying sources. It is target company's alternative point of view to examine construction company's project and business activity in a form of supply chain. Figure 17 introduces construction company's internal supply chain in order to produce completed project. Supply chain parties are design management, procurement and construction site. Nevertheless, design management is connected to owner's decisions and designers when aiming to provide designs, plans and specifications for procurement at right time. Managing design group with design schedule and design packages, and steering owner to decisions at right time are the most important tasks of design management in this supply chain. Creating procurement strategy and plan with procurement packages, and procuring subcontracts, materials and services based on designers' plans, designs and specifications are the most important tasks of procurement. Taking care of production and construction works with detailed schedules and completing the project are the most important tasks of construction site. Utilizing BIM in procurement and construction site should be included in the supply chain process from the beginning of the supply chain, thus BIM and data driven design is necessary. The purpose of this supply chain is to create value in every phase of the supply chain in order to eliminate waste, enhance cooperative relationships between parties and achieve improvements in efficiency, performance, costs and project delivery.

The use of the term "supply chain" in this thesis is defined to refer to the delivery of project's internal tasks. Principally, the supply of plans for the procurement, purchased from external designers and enabled by design management, is considered to be one of the main subjects

of examination of this thesis. Plans are considered to be mobile material-/service products that are supplied for the procurement in a chain of internal tasks within a project. Thus, in this way the use of the term differs from the traditional use of the term and the examination of the supply chain involving trade- and subcontractors in this thesis.

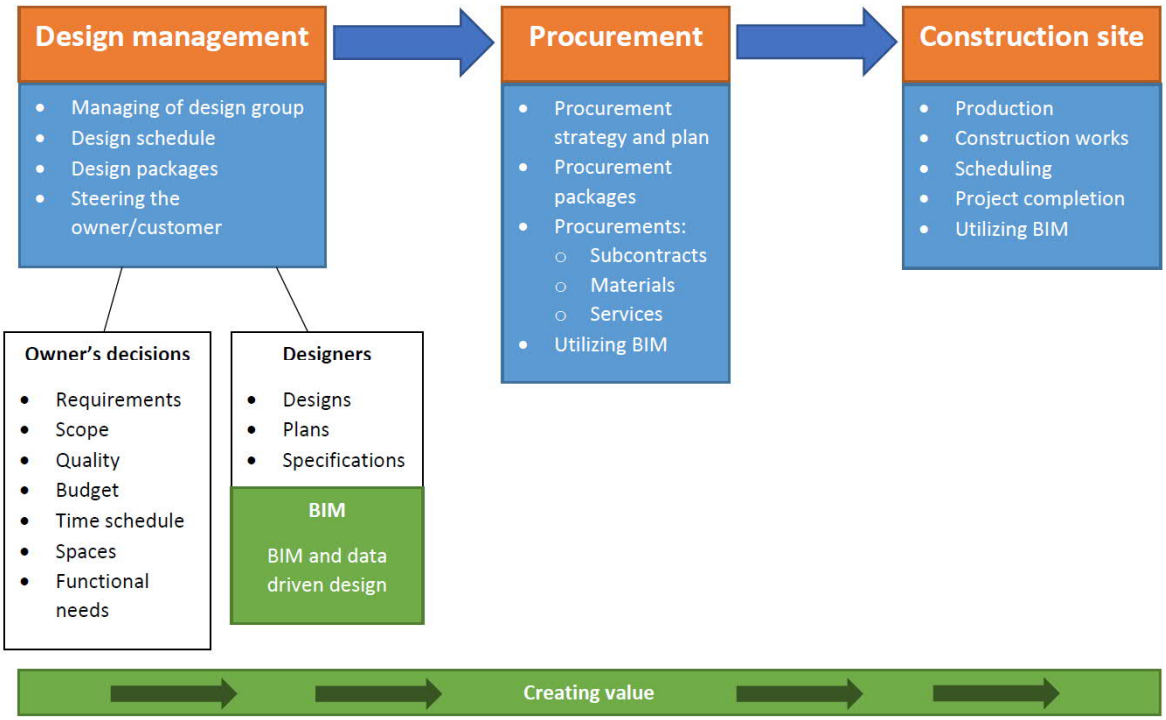

Figure 17. Construction company's internal supply chain process

2.7 Supply chain between design management and procurement

In traditional construction project delivery methods like DBB, detailed designing has already been made when invitation for tenders is sent for possible prime contractors. However, in CMR projects and own established projects detailed designing is done at the same time with procurement and construction. CMR projects have been traditionally defining design schedule by procurement packages but procurement packages directly have been suited poorly in design management and scheduling. Procurement packages have formed wrong and too small entireties for designing because with this procedure designer has to solve some bigger design entireties at the same time, which includes this smaller entirety as a part of it, when suddenly plans of a single procurement package are demanded. Due to this, designing should be made in such entireties that reciprocal dependencies of these entireties force into solutions at the same time. These entireties are called as design packages in SUKE-model. The purpose of design packages is to act as a tool for project's design and procurement distribution and scheduling those. Design packages are defined and formed in the beginning of the detailed design phase by design management collaboratively with designers, and they are formed project specific. The principle is to form design packages so that in terms of schedule parts planned in the same context and procured in the same phase constitutes one design package. (Kruus & al., 2006, pages 34-35.)

There are many good aspects and possibilities regarding to use of design packages. From the project management and schedule point of view, starting works at construction site is possible even though all plans are not ready, and owner and user gets more time for decisions and decisions considering transforming infill part. Design management is effective and also inspections about designs. Controlling design packages reduces the number of meetings compared to controlling procurements. From the design group point of view, design resources are distributed more evenly, and they can be increased more easily. The flow of information between different designers is easier, and easier also between designers and procurement. Design work doesn't pile up till the last moment and schedule created is not just a long line. Finally, from the procurement point of view, the content of design package is planned as one entity, but procurements can be distributed, and delivery of plans staggered. It is not compulsory to deliver all the plans for one procurement. In the design package inspection, instructions for desired quality and applicable level of plans can be presented. Design packages can be always composed for larger procurement entireties. (Kruus & al., 2006, page 35.)

In SUKE-model, design schedule must be made according to the design packages and the content of procurement packages will be formed after the design package is completed. The procurement distribution is not presented in the plans but in the invitation for tenders' commercial documents. Nevertheless, some procurement boundaries may need to be supplemented. SUKE-model utilizes building specification which describes design solutions related to the master plan and separate work specifications specific to the design package. Procurement schedules are traditionally created according to the procurement packages and the delivery order, but it has been suited poorly for design management. The delivery order of procurements is the reason why no inherent design entities are formed, and plan requests come as a surprise to designers. Pure procurement central model leads to early planning needs also with the transforming infill spaces where no decisions should be needed yet. In SUKE-model, procurement schedule is created grouped by design packages and this allows forming a common understanding between designers and prime contractor. (Kruus & al., 2006, pages 35-36.) The following Figure 18 introduces the difference between design schedule created according to procurement packages and created according to design packages. Design schedule and procurement schedule include the times of need for design packages, times for inspections and delivery times for plans for invitation for tenders (Kruus & al., 2006, page 36).

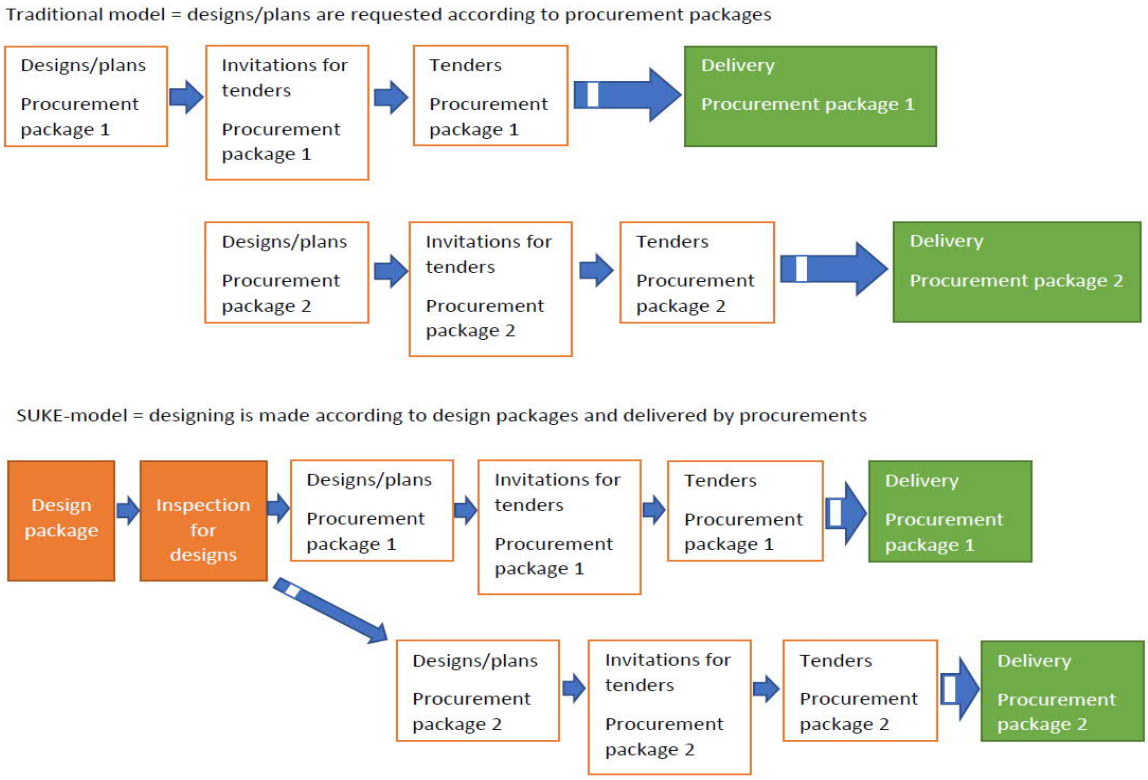

Figure 18. The difference between traditional model and SUKE-model design schedules (Customized based on reference: Kruus & al., 2006, page 36.)

The inspection for design package will be held by design management and designers when the package is completed before invitations for tenders. The cost estimation is compared to the target budget for the package, and cost estimation of the acceptable solution is assigned to the procurement packages. There are several things that inspection should include. The contents, solutions, readiness and adequacy of plans must be reviewed and verification of purpose of design solution must be done also in terms of cost. Making a common agreement about needed additions and changes to plans is essential, and instructions about the procurements of design package and the delivery times of plans must be given. Also, instructions about plans of invitations for tenders (how tender can differ from the solution presented in invitation for tenders, what plans are required from the subcontractor in invitation for tenders and what planning responsibilities are set for subcontractor) have to be given. Finally, instructions about the delivery of procurement plans must be given. (Kruus & al., 2006, page 37.)

The design package connects designs and procurements because it is accompanied by both the design documents and the procurements (Kruus & al., 2006, page 37). The connection between designs and procurements is important in point of view of prime contractor's internal supply chain between design management and procurement. Kruus & al., (2006, page 37) have presented an example of this connection in their book and it can be seen from Table 5.

Table 5. The connection between designs and procurements (Customized based on reference: Kruus & al., 2006, page 37.)

Prior plans must be designed.	Contents according to Talo 2000 classification. Numbering in chronological order.	Procurements without specifying material and type of work.
• Façade sections • Façade design details • Window and external door layouts • Façade roofs • Façade equipment	**6 Façade and external level plans by section** • Exterior walls, windows, external doors, façade equipment • Balconies, façade roofs • Special façade and façade roof plans	• Structural work of façade • Surface work of façade • Equipment works of façade • Sheet metal claddings • Windows and external doors work • External paintings

There are certain aspects, which also have effects on the supply chain process between design management and procurement, like the functioning of the market cannot be predicted in detail in advance, thus plans in the invitation for tenders do not directly determine the form of trade. Plans will develop during the different phases of procurement. The procurement strategy must be created, and procurement formats must be chosen for each procurement package. SUKE-model has six different purposes of use for plans in different stages of detailed design phase. The first stage is that plans for invitation for tenders are created according to chosen procurement strategy and format, which were presented earlier in this literature review. The second stage is that depending on whether the subcontractor decides to offer alternative solution in the tender or not, it must be decided that no changes will be made to the original plans or changes are made into the original plans or plans are given normative. The third stage is that plans are supplemented and developed so that subcontract includes unambiguous solutions. The fourth stage is that the plans developed during the procurement process and markings, which party is responsible for appendix plans and which party creates plans for construction work, are recorded into subcontracts. In the fifth stage, which is preparation stage, the plans are created as implementation plans. The final sixth stage is about creating final plans as agreed in the subcontract, and possible changes during construction work will be applied to the plans. (Kruus & al., 2006, pages 39-40.)

Appendix 1 presents an example of standard distribution of design packages and their content. Plans and procurements are also linked to design packages. Project specific planning and distribution of design packages is necessary because project's features and production order has influence on what kind of design schedule and design package distribution is relevant and more functional for the specific project. Nevertheless, standard design packages can be utilized as a basis for creating design packages and their distribution. It must be also understood that in residential construction the situation is totally different because there are more similar housing construction projects and commonality in production, thus systematic standard practices can be more easily utilized, but in business premises and competition construction, projects are often unique and more complex.

The supply chain process between design management and procurement is one chain part from the construction company's internal supply chain process and it is presented in the Figure 19 based on the earlier literature subchapters. The design management creates value for the procurement by delivering designs, plans and specifications from the designers to procurement at the right time. Design schedule and design packages act as a tool for this. The challenge is to manage the design group, where different design fields are involved, and steer the owner into decisions at right time. The supply chain process is complex because design schedule and design packages must be formed so that designing is staggered into suitable parts considering design work and owners decisions, while procurement distribution must be formed likewise into suitable parts considering invitations for tenders, procurements and work at construction site. Procurement strategy and formats have as well influence on the design work and schedule thus, there is obvious connection between design packages and procurements. The waste in the supply chain, which must be eliminated, consists of waiting plans, receiving plans too late, delivering wrong plans at wrong time (yet needless plans) and receiving uncomplete or inaccurate plans. These all aspects have influence on project delivery time, performance, quality and costs.

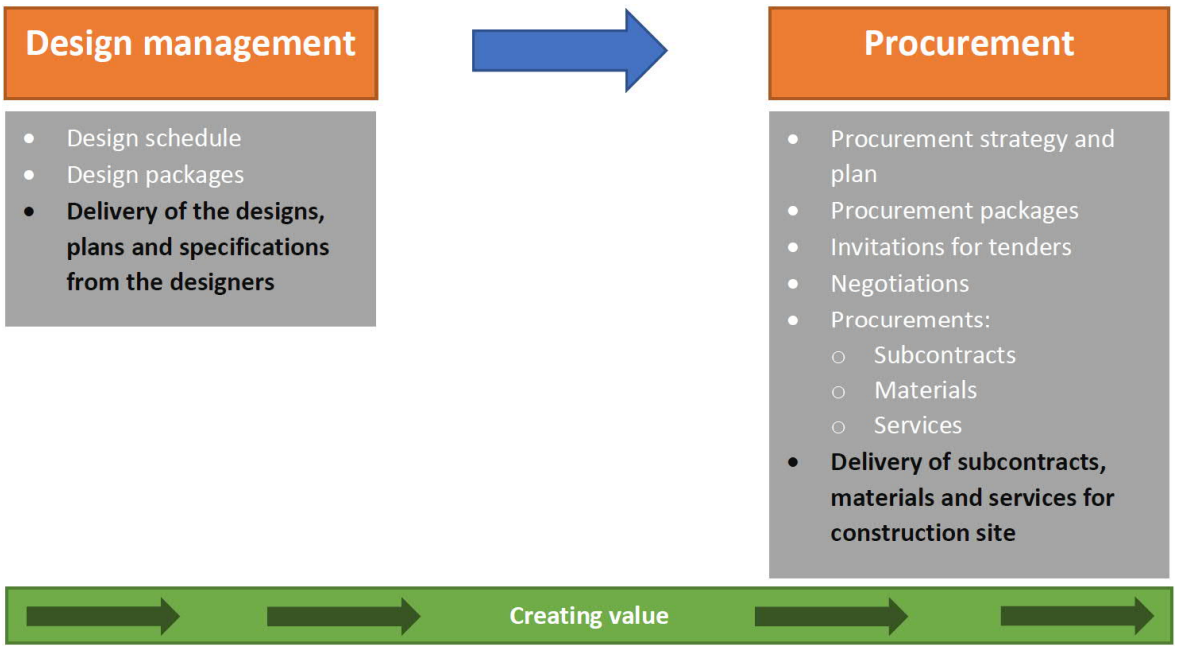

Figure 19. The supply chain process between design management and procurement

2.8 Building information modeling related to practices

Eastman & al. (2011, page 16) have defined Building Information modeling (BIM) as *"a verb or an adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation"*. Building Information Modeling results into building information model which characterizes the geometry, spatial relationships, quantities and properties of building elements, material inventories, geographic information, cost estimates and project schedule, and entire building lifecycle can be demonstrated with the use of model. (Azhar, 2011.); (Bazjanac, 2006.) Building information model is a three-dimensional model of a building which contains diverse information and information can be added almost

unlimitedly (Niskakangas, 2014, page 6); (Penttilä & al., 2006). Quantities and shared properties of materials can be extracted as a result from the model, and scopes of work can be isolated and defined. With help of the model, assemblies, sequences and systems can be shown in a relative scale within the entire facility or group of facilities. The important thing is that drawings, submittal processes, procurement details and other specifications can be interrelated. (Azhar, 2011.); (Khemlani & al., 2006.)

The model can be either the original model or translated to a common data format IFC-model (Industry Foundation Classes). The difference between the models is that original model is the model designed by the designer in the operating format with which it is produced, and IFC-model is an open file format developed and maintained by the buildingSMART International-society. (Niskakangas, 2014, page 6.); (RT 10-11066, 2012) The purpose of the IFC file format is to distribute and transfer data from models between programs of different software providers (BuildingSMART-International, 2020). Different design fields model their own building information model when they are designing the building. Architect produces architect model which acts as a basis for every other design field's model (RT 10-11068, 2012). Other models are for example structural model and HVAC/MEP models. To ensure the quality of BIM driven building designing, a combination model is combined from all these different design field models. In combination model, the compatibility of the models is reviewed and the discrepancies in the design solutions can be identified earlier before the problem reaches construction site. Combining and reviewing building information models is done by the lead of main architect or person in responsible due to contract together with the design group. Each designer is responsible for updating their own models if changes occur in the reviewing of combination model. The combining of models is done by using IFC-format files. (RT 10-11071, 2012.)

The building information model can be used for many purposes, for example for visualization, cost estimating, production drawings, code reviews, construction sequencing, forensic analysis, facilities management and conflict, interference and collision detection (Azhar, 2011). Building information model provides also several benefits and the key benefit is its accurate geometrical representation of the parts of a building in an integrated data environment (Azhar, 2011); (CRC Construction Innovation, 2007). Furthermore, other benefits are better design, faster and more effective processes, controlled whole-life costs and environmental data, better production quality, automated assembly, better customer service and lifecycle data (Azhar, 2011).

Khemlani (2007) describes some features of BIM that has been used and utilized in construction industry. For example, ability to work on large projects and to support distributed work processes, with multiple team members working on the same project, have been utilized. Multi-disciplinary capability of BIM has served architecture, structural engineering and MEP as well as ability to support preliminary conceptual design modeling. One of the most important features is that BIM has full support for producing construction documents and there is no need for another drafting application. Traditional CAD management tasks have been reduced by BIM's automated setup, management and coordination, and availability of object libraries have served the design work. Construction projects have become more efficient as BIM has direct integration with project management, cost estimating, structural analysis and energy analysis applications. BIM has been utilized also to support construction-related tasks such as quantity take-off, estimating, and four-dimensional scheduling. (Khemlani, 2007.)

In Finland, there are common building information modeling requirements 2012 (YTV, Yleiset tietomallivaatimukset, 2012) available for use at construction industry which are results from a large-scale development project COBIM. The goal of real estate and building modeling is to support quality, performance and safety of design and construction, and to support project and lifecycle process according to sustainable development. Minimum requirements for building information modeling and information contents of models are presented in these requirements. In addition to the minimum requirements, additional requirements may be imposed case by case basis. Modeling requirements and content must be included in all design contracts bindingly and consistently. The common building information modeling requirements consists of 14 parts and the first part considers the general issues that all parties should be familiar with if the building information modeling is used in the construction project. Talo 2000 classification acts a tool for functional determination of space. (RT 10-11066, 2012.)

According to common building information modeling requirements, building information models allow one to support investment decisions by comparing the functionality, scope and cost of the solutions. Comparison of energy, environmental and lifecycle analyses solutions for design and maintenance target monitoring are possible too. Plans can be illustrated, and constructability analyzed. Quality assurance and data transfer can be improved, and the performance of design process increased. (RT 10-11076, 2012.) General objectives for BIM are presented, as for example to support decision making of the project and to engage the parties in the project objectives trough the building information model. Other objectives are to illustrate design solutions as well as to help designing and coordinating plans and increase the performance of processes during construction. BIM should increase and ensure the quality of the construction process and end product as well as support project's data transferring for operating phase's information management. It should also support project's cost and lifecycle analyses and increase safety during construction time and lifecycle. (RT 10-11076, 2012.)

The common building information modeling requirements recommends that the owner's construction manager designates a suitably qualified and knowledgeable person to a BIM coordinator's role at the very early start of the project. The BIM coordinator is responsible for the preparation of the project-specific preliminary building information modeling plan and the coordination of the modeling tasks in the different design areas. The role of the BIM coordinator, together with project management, is to describe the building information modeling goals, objectives and scope of the use. Coordinator explains to each party the building information modeling tasks, responsibilities and obligations. The guiding, coordinating and steering of building information modeling tasks are to be performed throughout the project in collaboration with the main architect. BIM coordinator's duties may include also producing a combination of models and ensuring the coordination of information technology, or it can be set for designer or other party. (RT 10-11076, 2012.)

There are existing general theoretical definitions when working with BIM projects and couple examples of them can be the employer's information requirements (EIR) and BIM execution plan (BEP). EIR determine the information that will be required by the employer in BIM project. The information will be required from both employer's own internal team and from suppliers for the development of the project and operation of the completed building. The possible suppliers respond to the employer's information requirements with a BEP from

which their proposed approach, capability and capacity can be evaluated before making a contract. The purpose of BEP is to set out the supplier's competence to meet the EIR. It is recommended that the EIR must contain information management, commercial management and competence assessment aspects. For example, information management aspect should contain LOD requirements, training requirements, planning of work and data segregation, coordination and clash detection, a schedule of any specific information to be excluded or included in information models, requirements for tenders' proposals for the management of the coordination and the collaboration processes etc. (Designing Buildings Ltd, 2020.)

2.8.1 Building information modeling and design management

Design management with BIM includes reviewing project's design objectives, comparison of objectives into requirement models and monitoring of compliance with design objectives at proposal, master plan and detailed design phases. BIM is initiated for all design areas and outputs from the design phases, derived from the building information models, are assembled to support the owner's decision making. Design management is used to ensure that objectives are met and compatible with each other. Design management manages the cooperation between different design parties and inspections about plans and approval as well as reporting procedures are agreed before the designing work starts. Design management controls the design process with design schedule and design packages which act as demands for building information modeling and design work. (RT 10-11076, 2012.) The building information model is always published for a specific use and the publishing decision is usually triggered by the design schedule (RT 10-11066, 2012). In the detailed design phase, building information models are developed to meet the determined level of development in order to advance into the invitation for tenders phase (RT 10-11076, 2012).

Level of development (LOD) specification allows construction industry professionals to articulate how an element's geometry and associated information has developed throughout the entire process when building information modeling, and it signifies the degree to which different members of the project can rely on information associated with an element (UNITED-BIM, 2020). BIMFORUM (2015) defines the LOD specification as *"a reference that enables practitioners in the AEC Industry to specify and articulate with a high degree of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process"*, and reports that LOD schema was originally developed by the American Institute of Architects. There are six different degrees of LODs and they are presented as follows:

- LOD 100
  "The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements."

- LOD 200
  "The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element."

- LOD 300
  "The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element."

- LOD 350
  "The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, location, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element."

- LOD 400
  "The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element."

- LOD 500
  "The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements."

(BIMFORUM, 2015.)

Uusitalo & al. (2019) describe that the project team parties need to have a common view and collaboratively agree on how to use BIM standards or adjust them based on the project's information need when determining and applying LODs for project's building components. The needs are dependent on the responsibilities of design management, procurement and production as well as different contract forms, thus LOD determination needs to be a pull-based process which takes account the point of view of production and procurement. Determination of LODs must be still sensible and the article states that the developed overall Lean Design Management process aims to minimize designers rework and prevent production delays caused by incorrect design due to overly accurate LODs too early in the design process. Prime contractors have demanded too accurate design and too much information too early in the project and there have not been common understanding among project stakeholders of what LOD levels and information is required for each procurement package. Thus, the outcome has been incorrect design which does not meet the procurement's requirements and delayed design. The intention is to steer the project stakeholders to collaborate and discuss the information needs with building information models related to different procurement packages and achieve a common understanding of issues among parties. Generally, waste is reduced from the modeling process and entire design process as well as procurement process improving the productivity of the project. However, LODs are thus defined to become more precise on the different phases of design work from a coarser drafting level to a more accurate procurement level and later even more accurate production level. (Uusitalo & al., 2019.) Procurement strategy and procurement formats influence the determination of LODs from a procurement perspective. With procurement format, one can describe in general the needed level of planning required for certain procurement package and thus parties can communicate better what is the required LODs for building components considering the procurement in question. A common view about procurement strategy and formats between design man-

agement and procurement is required to enable fluent design work. Nevertheless, one solution to such strategic issues is to define procurement format in collaboration with design management and procurement in this Thesis. Solution proposition for this Thesis' problem will be described in the chapter 4 utilizing background knowledge from this overall Lean Design Management process in question and going more deeper into strategic process itself.

Nevertheless, in Finland, common building information modeling requirements describe yet different kind of level of development levels than LODs at this moment. There are three different similar levels which are level 1, level 2 and level 3. The desired modeling level for each building component can be chosen for different stages of the project. (RT 10-11068, 2012.) Choosing the levels for each building component correctly and project specific is important in the point of view of the supply chain between design management and procurement because procurement strategy and procurement formats have influence on which kind of levels are needed. Procurement wants as well utilize proper quantities in the invitations for tenders, thus BIM can create value for procurement by registering quantities into modeled building components. The common building information modeling requirements include appendix which contains table where these levels can be determined for each building component (RT 10-11068, 2012). Finnish building information modeling content levels are introduced as follows:

- Level 1
  The purpose is communication between designers and coordination of plans. The location and geometry are modeled according to requirements and building components are named descriptively.

- Level 2
  The purposes of use, in the program planning and design proposals phases, are energy analysis and, in the production planning phase, component-based cost estimation. The location and geometry are modeled according to requirements and the type of structure is defined with correct name. Production subassembly parts are modeled so that number of pieces and other relevant quantity information can be exported by the product types from the model.

- Level 3
  The purposes of use are construction site's scheduling and procurements. The location and geometry are modeled according to requirements and essential information considering procurements is included in the building components and they can be listed. For example, a window contains information about its type, aperture size and decibel requirements etc.

(RT 10-11068, 2012.)

In the procurement serving planning phase, building information models and quantity lists produced from them and visualizations as well as other documents are provided to tenders to facilitate the tendering process and preliminary planning of construction work. Quantity calculation from building information model speeds up the calculation and gives a more accurate result provided the modeling has been done correctly and without error. BIM based quantity calculation and ready-made report templates for quantity lists eliminate a significant

amount of duplicate work, which improves construction productivity in this regard. Procurement can utilize building information models and their quantity lists as documents for invitations for tenders. (RT 10-11066, 2012.)

The role of design management is important when Finnish model content levels are determined for building components because these determinations create the prerequisites for using the building information model in procurement. The following Figure 20 presents an example from the list of content requirements for the Architectural BIM at various phases of the project. Levels are marked from one to three, and whether they are mandatory or optional.

NOA= Needs and Objectives Assessment, SD=Schematic Design, DA=Design of Alternatives, DEV–Design Development, BPE–Building Permit, DET–Detailed Design, BID–Bidding, CON=Construction, H =Handover, MAIN=Maintenance

M=Mandatory; level of accuracy will be agreed on a project basis (M1, M2, M3 = recommended levels)
O=Optional; level of accuracy will be agreed on a project basis (O1, O2, O3 = recommended levels)

Talo 2000 classification	NOA	SD	DA	DEV	BPE	DET	BID	CONS	H	MAIN
12 Building elements										
121 Foundations										
1211 Footings (based on the structural BIM)										
1212 Enclosure walls				M1	M1	M2	M2	M2	M2	M2
1212 Foundation beams										
1212 External surfaces										
1219 Special foundations										
122 Ground floors										
1221 Ground floor slabs		O1	O1	M1	M1	M1	M1	M1	M1	M1
1222 Ground floor ducts				O1	O1	O1	O1	O1	O1	O1
1222 Ground floor ducts; grates, covers, hatches etc.						O1	O1	O1	O1	O1
123 Structural frame										
1231 Shelter floors			O1	M1	M1	M2	M2	M2	M2	M2
1231 Shelter walls			O1	M1	M1	M2	M2	M2	M2	M2
1231 Shelter roof structure			O1	M1	M1	M2	M2	M2	M2	M2
1231 Shelter closed space, emergency exit corridors and openings				M1	M1	M2	M2	M2	M2	M2
1231 Shelter protective doors and hatches				M1	M1	M2	M2	M2	M2	M2
1231 Shelter ladders and ventilation equipment				O1	O1	M1	M1	M1	M1	M1
1231 Shelter crises-time and other equipment				O1	O1	O1	O1	O1	O1	O1
1232 Bearing walls		O1	M1	M2	M2	M2	M2	M2	M2	M2
1233 Columns			O1	M1	M1	M1	M1	M1	M1	M1
1234 Beams			O1	M1	M1	M1	M1	M1	M1	M1
1235 Intermediate floors		O1	M1	M1	M1	M2	M2	M2	M2	M2
1236 Roofing decks		O1	M1	M1	M1	M2	M2	M2	M2	M2
1237 Structural frame stairs and landings		O1	O1	M1	M1	M2	M2	M2	M2	M2
1237 Structural frame stair railings				O1	O1	M1	M1	M1	M1	M1
1239 Other structural elements				O1	O1	O1	O1	O1	O1	O1

Figure 20. An example from the list of content requirements for the Architectural BIM at various phases of the project (RT 10-11068en, 2012.)

Tauriainen & al. (2016) have presented the guideline for recommendations and activities in order to improve design management practices. The design discipline-specific project managers must be experienced in BIM, and BIM consultation should be acquired, if they are not familiar enough with BIM. It is important to understand the differences between BIM and two-dimensional Cad projects. The main BIM coordinator must be named at the beginning of the projects and is responsible for modeling instructions, integrating and clash checking models. Also design discipline-specific BIM coordinator should be named and acts as the project manager's support. BIM related ways of actions and instructions must be specified at the beginning of the project and utilizing the national Common BIM Requirements and LODs is highly recommendable. Design group meetings have to be organized and the main

structural engineer or modeling coordinator must publish the comprehensive modeling instructions for hole circulation before the hole provision phase. The hole circulation must be made firmly according to the schedule and several iteration circuits must be avoided. Design and modeling meetings have to be pre-scheduled for controlling activities, BIM contents and communications between design group parties. Difficult design issues can be solved for example in knotworking sessions. The last thing presented is that project feedback must be collected when handing-over projects in order to learn. (Tauriainen & al., 2016.)

2.9 Summary of the literature review and formation of theoretical framework

Improving the supply chain process is a continuous process which is all about creating value in the supply chain and eliminating waste from the processes. The design management must create value for the procurement by providing scheduled designs and plans for procurement at right time with correct content. Project delivery method has a huge influence on responsibilities of the project stakeholders and this Master's thesis concentrates on project delivery methods where prime contractor is in charge of design management.

Construction company's internal supply chain process consists of three supply chain members which are design management, procurement and construction site. Despite this, the supply chain has external sources that will have influence on the chain. For example, the owner's decisions and working of designers. The purpose of this supply chain process is to create value during the process until the construction of a building is completed. Design management manages the design group and coordinates the design work in order to achieve set targets and provide plans for procurement. Procurement purchases subcontracts, materials and services according to the plans from external sources in order to serve the needs of construction site and make profit. Production is implemented at construction site by managing subcontractors who will execute construction tasks according to the order of construction tasks and finally in the end project is handed over to the owner. The focus is in detailed design phase between the internal supply chain members design management and procurement.

Based on the literature review, it was found that Kruus & al. (2006) SUKE-model can act as a basic framework solution to be developed for this thesis and at the same time it answers to the research question what is the process by which design management can produce plans that serve procurement at right time. Design schedule, design packages, procurement strategy and procurement formats are at the center of this internal supply chain part. In SUKE-model the focus is much on the point of view of owner and design management, while prime contractor's perspective and procurement are paid less attention. Due to this, the processes described in SUKE must be developed and improved to serve prime contractor's needs, in order to produce fluent construction project for both the owner and prime contractor.

Utilizing BIM and data driven design is important for being able to improve design work, coordinate plans and increase the performance of processes. Many design problems or issues relating to the plans can be solved and corrected earlier in the design meetings with help of combined building information model before they reach procurement and construction site. The ability of BIM to support distributed work processes is emphasized when considering large and complex projects where designing work is done at the same time with procurement

tasks and construction work. For procurement, the quantity take-off from building information model is the most important tool for eliminating waste on unnecessary calculations of quantities from the two-dimensional plans. When building component quantities can be taken-off from building information model, it creates value for procurement and saves a lot of time from the procurement process.

Based on the literature review, collaboration between design management and procurement is required. Design packages and procurement packages should be sensible and aligned, if the supply chain is to be improved, and they are controlled by design schedule and procurement strategy and plan. In SUKE-model, design schedule and design packages are created according to procurement strategy and formats, and procurements are later distributed and formed according to design packages. Nevertheless, it is not efficient enough because procurement distribution should be formed at least at some level when scheduling design schedule and forming design packages to prevent future problems and changes considering the delivery of plans. Project specific collaboration between design management and procurement is needed when forming design schedule, design packages, procurement strategy/plan and procurement packages. The following Figure 21 combines and illustrates the author's own thoughts about the links between design management and procurement in the construction company's internal supply chain.

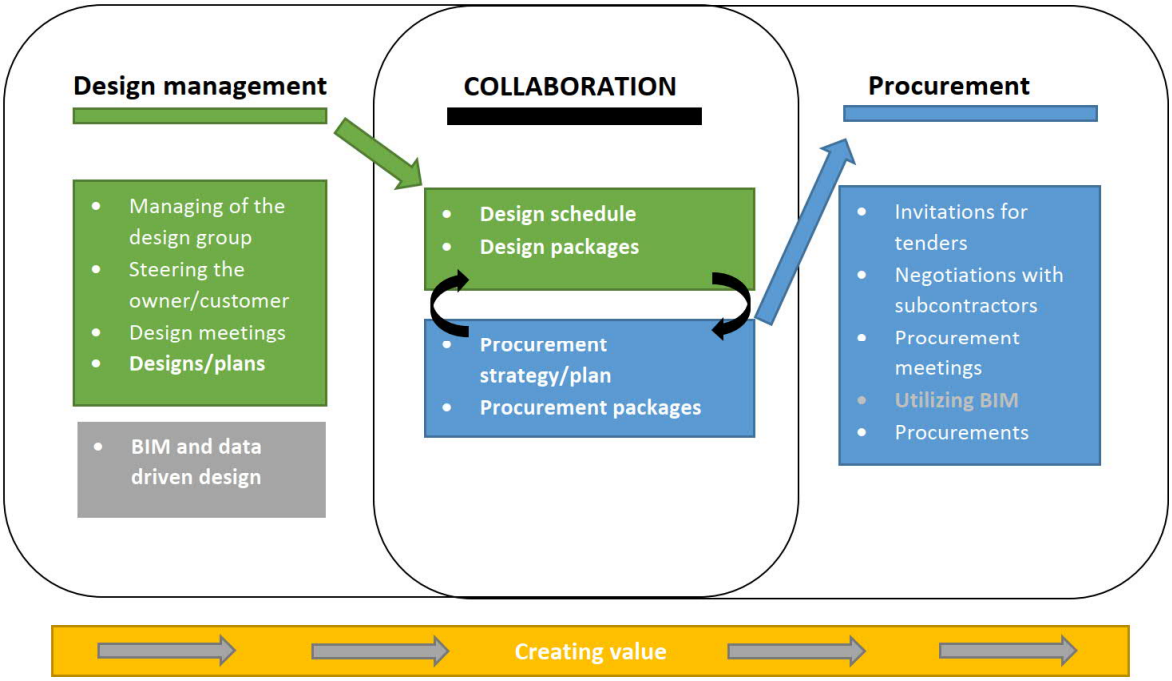

Figure 21. Theoretical framework

The discoveries from the literature review act as a good basis for interviews and solution proposition for improving the supply chain process. The basic framework solution can be utilized while constructing interviews and compared to the opinions of interviewees who are professionals at construction industry. Construction of proposition to improve the supply chain will be created according to the discoveries from the literature review, data search from company's databases and interviews.

3 Present state of the company's practices and development targets

This chapter contains mapping the company's current state related to the supply chain practices between design management and procurement. Guidelines and instructions were searched from the company's databases in order to get an understanding what kind of practices company has and is there enough guidance and help available for employees. Interviews were constructed and held about the present state of the company's practices, challenges and problems as well as development propositions. In the last subchapter (3.4), synthesis of the main findings is provided.

3.1 Data search from company's databases and tacit knowledge materials

Target company's current management system database was searched in order to find existing guidelines and instructions about procedures related to design management and procurement processes. Current management system database serves as a management tool and supports construction company's processes and daily operations. Company's databases were recently distributed because of fresh merger of two construction companies and due to that information was distributed into different locations as well as databases and there was not only one common database for use where to find information. Nevertheless, a new common management system database has been newly taken into use. It is intended that there will be all official usable guidelines and materials for daily use, but it is partly incomplete yet even though existing data, information, guidelines and instructions have been tried to transfer into this new database. Some data may still have been inadvertently left untransferred to the new database and some projects may still use guidelines from older databases. Due to this, also older databases were searched and during searching some tacit knowledge materials were also received which are not in the company's management system database. However, the data search was accomplished by going through all the existing databases with detailed search. Some of the found instructions are outdated and some of the new instructions are incomplete or must be improved.

There are existing several process cards, guidelines and instructions considering design management and procurement. Nevertheless, the information was found from different databases and the arrangement of the information was somewhat unclear. It was difficult to find where certain information could be found and what information should be sought. Thus, you should know beforehand what information you are looking for, ergo, if one is a new employee and in a new job title, it can be difficult for one to orientate oneself into what tasks one should perform in the job. It is necessary to improve the content of the new database, but it doesn't concern this Master's thesis subject and is limited outside of the scope.

Design management

It was discovered that there is a process card considering design management in general, covering the different phases of the project. The process card instructs to create and monitor design schedule, and procurement packages and design packages must be also created. Productization solutions and prefabrications should be considered too. The level of description is very general and instructs only what things should be done at certain project phases.

The main points are discussed, but their implementation and responsibilities of persons remain unspecified.

Another process card found is about project-specific action plan of design management. It describes the targets and the requirements for design management and instructs that design options must be examined and chosen. Other measures required are for example design component or design task management and creating design schedule. Even though design schedule is mentioned, the process card doesn't describe what kind of is the process relating to it. Very general things are discussed and same kind of theoretical aspects, as presented earlier in the literature review about purposes of design management, are mentioned. Design management ensures that plans meet the design objectives and are completed for sales, cost estimation, procurement and production.

During data searching, it was found that there is one over ten-year-old document which is about design schedule and procurement schedule. However, it is more about procurement schedule than design schedule because in the example schedule it describes the needed times for plans by procurement and not by design package. One four years old document discovered is about procedures of design management. It instructs that project manager must create design schedule and mark times for inspections about designs into it. Designers are obligated to publish building information models into project bank as agreed and update the plan catalogue. The content of building information model and modeling method must be presented in the BIM instructions and data content tables. The information produced from the model is used for example in design management, quantity and cost estimation, procurements, task planning and scheduling.

A certain example of old design schedule was found as well when searching databases. The design work in the schedule is scheduled so that designing is divided into different design fields which are architecture, geoengineering, structural design, HVAC-design and electrical design, and each of these contain their own scheduled steps. Procurements are distributed into different subcontracts and scheduled so that plans are done before procurements are implemented. Nevertheless, the schedule doesn't involve design packages or procurement packages. It can be difficult to monitor this kind of design schedule and the connection between plans and procurements is a bit frail, if compared to the SUKE-model described in the literature review. Also, late decisions of the owner or the customer cannot be allowed. Otherwise, the construction schedule could become longer.

An old Excel file was discovered about schedule of plans and the document instructs that design schedule is a different thing than schedule of plans. Design schedule should be such that schedule of plans could be implemented when design schedule guides designers. Design responsibilities must be reviewed with parties before planning begins. It was mentioned in the file that design management can easily be tempted to let designers decide among themselves the order in which the design tasks will be performed. However, the chaotic design process cannot produce flawless designs and it is therefore essential, for the quality of the construction, to manage designing and ensure fluent designing.

A good instruction document was found about design management during construction, although it is eight years old. It describes first that the purpose of design management during construction is to ensure that design work is proceeding in the order required for procurement and production. New innovations provided by production organization and subcontractors,

which will have improving effect on project's cost, technical aspects or functionality, must be considered and examined. Plans delivered for the production must be flawless, consistent and in line with the latest design decisions. Project manager or construction manager is responsible for design management during construction. The document suggests that the building is divided into different blocks and designing is implemented based on these blocks and order of tasks. The design schedule is created as well based on the chosen blocks. By dividing the building into blocks, the detailed design phase avoids overloading the design work and the plans are completed in the right order. The following stages are instructed in the document for the progress of design management:

1. **Ensure schedule**
   Specify schedules for both construction and procurement, and make an agreement about the necessary information for invitations for tenders and procurements. Make an agreement on the measures to be taken in case of any delay in the plans.

2. **Prevent design risks**
   Make an agreement about time schedule for inspections about plans, and make also agreements about updating plans in design meetings. Ensure information flow between designers and continuous coordination of the plans. Keep inspections about plans and record the issues that have been processed. Make an agreement about marking joint detail drawings in the plans.

3. **Ensure the delivery and updating of plans**
   Engage designers to make a list about the plans that must be drawn. Make an agreement about the delivery of the plans and numbering of the plans.

4. **Make an agreement about accepting process of additional and alteration works as well as alternative designs**
   Make an agreement about manners of marking changes and time for solving the costs emerged from changes because it will have an effect on construction schedule. Make an agreement that who will be responsible for cost investigation and agreement of possible alternative plans.

5. **Collect and document feedback**
   Make an agreement about documentation of design errors and their corrections. Have a meeting for criticism at the end of the project and record your feedback.

6. **Make sure that changes during construction are accepted by the owner**
   Document approval at construction site meetings.

7. **Make sure that the information in the final documents is updated to reflect implementation**
   Ensure that the final documents include the information collected from implementation drawings. Make sure that the final documents are constructed according to the instructions given.

The same document includes a list about plans needed to be completed when starting the construction work at site and instructs that if many of these plans are missing or incomplete at the start of the construction phase, special attention must be paid to design management

and the design schedule must be checked for interference. Also, an indicative list of plans for implementation is introduced in the document. Another document was discovered as well which contains comprehensive catalogue about plans for construction project.

It was discovered that housing construction segment has an Excel file about design schedule including project phases, design packages and plans from different design fields. Procurements are not included in the design schedule as the nature of business is different in housing segment than in business premises segment. The file in question and its properties are not directly suitable for this Master's thesis solution proposition because in housing construction the plans are much more completed when construction work begins at site than in complex business premises projects where the owner makes late decisions and designing is done parallel with procurement and construction work. Nevertheless, it can provide good pointers and help with what a solution might be when developing the proposition for improving the supply chain process.

Procurement

It was discovered that there is a process card considering determining procurement packages and design packages. The purpose is to divide the project into entireties that can be procured at a time without open interfaces between the procurement packages. The initial data for packages is obtained from cost estimation department, unless the distribution of packages is already formed at the cost estimation stage when cost estimating engineer and procurement engineer create the distribution in cooperation. The design packages must be designed to support procurement packages. It was instructed in the process card that one procurement package requires usually plans and initial data from several different designers which can be for example, architect, structural designer, HVAC-designer or geoengineer etc. Direct guidelines for the procedures to be implemented are instructed as follows:

- Assemble the procurement nomenclature at the title level into a simplified procurement entity based on a standardized procurement plan template. Please note the following points:
    - Take into account the views of cost estimating when creating packages. Please also note the advance tenders received. Packages are formed in collaboration between cost estimating and production.
    - Define the content for the procurement titles (quantities, distribution of building blocks, budget, indicative schedule, required initial data from designers).
    - Define critical procurement titles considering the project (critical path).
    - Define the method of delivery for the package, if possible (subcontracting, materials delivery, production subassembly, service contract, etc.) taking into account the contract limits. Please also check package logistics. It is recommended that the package should be able to be implemented continuously or clearly in stages.
    - Identify a possible annual contract option for the package.
    - Identify the possibility of bundling between projects.
    - Seek to identify opportunities for international procurement when forming a procurement package.

- Take into account the needs of design management, owner, designers, and investors. If necessary, get an approval for the procurement package distribution from the owner.
- Define the required design packages to support the implementation and procurement of procurement packages along with design management and production. Ensure that the contents are unambiguous to all parties (designer and own organization).

It is instructed in the process card that project's responsible procurement engineer is primarily responsible for creating procurement packages. Nevertheless, these packages will be formed in close cooperation with design management (design packages), production and cost estimating. The guidelines are well and clear in the process card, but the connection between design packages is not brought out much. The process card in question is supported with an Excel file where responsibilities regarding the procedures to be implemented are defined. Project manager or construction manager is responsible for the procedures, but procurement engineer is the executing party, and what comes to the relationship between design packages and procurement packages, the executing parties are design management and procurement engineer.

Another process card discovered covers creating procurement plan and updating it. It states that the primary purpose of procurement plan is to act as a tool for procurement engineer for organizing the procurements of the project. From the procurement plan, the procurement schedule and the accumulation of procurement costs can be monitored as well as it can be used as a reporting tool for example for the owner or developer. The initial data for the procurement plan comes from the procurement packages. Other required information will be determined in collaboration with production and design management. The procurement plan will become more detailed as the project progresses. Direct guidelines for the procedures to be implemented are instructed as follows:

- Prepare a procurement plan on standardized template. The standard base allows for example bundling over projects, reporting comparisons etc.
- Define the final schedule for the procurement packages (start date, invitation for tenders, submission, negotiation, awarding contract, etc.). The schedule must take into account the decision-making time required by the owner.
- Determine also the schedule for needed initial data (the plans) and their delivery responsibilities (responsible designer).
- Pay particular attention to procurement packages which have a long delivery time (usually these packages belong to critical procurements).
- Determine the rest of the information for the procurement packages (budget from the goal estimate, quantities, responsible purchaser, procurement preparer, internal work opportunity, advance tenders, seasonal contracts, international sourcing, production subassemblies and denomination/procurement package code) as accurately as possible.
- Identify any purchases that are the responsibility of the owner or user and exclude them at the procurement planning stage at the latest.
- Considering the owner's purchasing responsibilities however, the obligations incumbent on the prime contractor must be taken into account.

- Identify the possibility of bundling across project boundaries. Bundling is also possible as the project progresses. Procurement packages are as well possible to chop or merge as the project progresses.
- Procurement plan must be saved and maintained in project workspace.

The project's responsible procurement engineer is responsible for creating the procurement plan and it is made in a cooperation with design management, production and cost estimation. Also, maintaining procurement plan is taken care by procurement engineer.

An old document about procurement plan was found while searching data. It instructs that company's procurement strategy must be obeyed and strategic priorities have to be defined on a project-specific basis by construction manager. The quality and readiness of the plans must be commented by procurement and production, and possible deficiencies must be found from a procurement perspective. Project manager is responsible for managing design work based on received comments and making design schedule. Procurement engineer creates procurement plan and determines procurement entities in collaboration with construction manager or construction site manager. The design schedule must be commented by procurement engineer and it will be updated based on comments.

A kind of guide for procurement package planning progression was brought out in one old email received from a head of developer contracting. It describes the steps that are needed when forming procurement packages and these steps are presented below:

1. The initial data meeting
2. Planning of the entirety
3. Inspection about the plans
4. Planning of the procurement packages
5. The inspection about procurement packages
6. Procurement process moving forward from the inspection
7. Scheduling of the procurement packages.

Also, a procurement package card template was received, and it can be used when planning procurement packages. It contains title of the procurement package, the content of procurement package, the schedule of procurement package, the initial data for procurement from designers, the necessary plans and a timetable, saving into project bank, the date for inspection about procurement package and other considerations. This card seemed very useful for forming more accurate content for one procurement package. An old document was discovered too during data search which contains a catalogue about plans needed for procurement from different design fields.

Design management and procurement

It was discovered that there is a process card considering creating and maintaining project's design guide. The primary purpose of design guide is to act on organization of the project, the definition of responsibilities and the setting of targets. The defined design schedule, project card, design packages and procurement packages are part of the design guide and it will become more accurate as the project progresses. Direct guidelines for the procedures to be implemented are instructed as follows when creating design guide:

- The design guide is project-specific, and it defines the design fields and responsibilities required for the project, as well as project responsibilities and approval practices.
- The design guide includes setting targets, defining work packages, design packages and procurement packages as well as design schedule based on general schedule.
- The design guide defines the working methods, tools and meeting procedures for the planning phase, as well as the approval procedures and the decisions-making timetable.
- The design schedule is determined for the design packages (start date, invitation for tender, submission, negotiation, awarding contract etc.). The schedule must also take into account the decision-making time required by the owner.
- Also, defining the schedule for initial data (plans) and their suppliers (responsible designer) must be done.

The roles for implementing the process card in question are presented only in general so that parties involved are project manager, design management, construction management and procurement engineer.

The process flowchart considering procurement was discovered and it instructs to consider productization solutions and prefabrications in the project and create procurement packages and design packages as well as form procurement plan. The process is described at very general level, thus there is a need for more accurate describing of the process between design packages and procurement packages, but it could be separated from this process flowchart as own process flowchart.

A process flowchart concerning a certain huge project was received from a head of developer contracting. The process flowchart in question is very good and describes well the process entity considering detailed design for procurement. Design packages and procurement packages are utilized in the process and design schedule and BIM schedule is created. The distribution of design packages is done based on determined building blocks. Inspections about design packages are held and the plans are delivered for the procurement. Nevertheless, it doesn't describe the relationship between design packages and procurement packages or what kind of the process is when creating design packages and procurement packages.

The subject and challenges of this thesis have been discussed in the target company as, for example, a certain old PowerPoint presentation has been about coordination of design management and procurement. The presentation contains a lot of questions about design packages and procurement packages but doesn't give any direct guidelines for acting in the process. Also, few properties of SUKE-model are presented and discussed lightly but solution propositions are not provided. One observation was that it is mentioned in the presentation that there is not enough time for discussion about what we are doing in this certain project and how. From this, it can be concluded that resources must be properly allocated to project planning from the outset. Without necessary resources, it is impossible to succeed with creating design packages and procurement packages.

Building information modeling

It was discovered during the data search that there is only little guidance and instructions available considering building information modeling and its purposes of use. Some instructions and trainings are available in the database considering the use of programs related to BIM activities and how to retrieve quantities from the building information model. Nevertheless, documents and guides for getting deeper understanding of BIM and its properties are not provided at this moment. Common BIM Requirements exist in Finland but probably especially representatives of older generations don't even know that these requirements exist or where they would find information relating to BIM activities or general principles. Understanding of LODs and other issues are necessary if one is working with BIM construction projects and managing design work.

Certain instruction about job description of BIM coordinator was found during search and it is very general and short. It states that BIM coordinator coordinates design group's BIM working with project owner or design management and main designer. Building information modeling must be scheduled into a design schedule and its implementation overseen by BIM coordinator. Coordinator ensures together with main designer that building information models from different design fields form a coherent entity. Building information model meetings and reviews must be prepared and held. BIM coordinator is responsible for combining different design field models into common combined model and making collision inspections according to Common BIM Requirements. Also, visual and rule-based inspections about different design field building information models and combined model must be made. BIM coordinator is as well responsible for quality assurance tasks which are directed to owner's or design management's responsibility. Finally, it is stated as well that the coordinator will support the design management and provides BIM program training for the project if needed.

It was discovered that Housing segment has their own guideline for BIM projects which is at the same time BIM plan that is updated during the project, but it is not valid or used in business premises segment because of the different nature of the construction projects in housing construction. Nevertheless, it contains similar things that must be considered and modified by their content in the business premises BIM projects like instructions about project organization, project information management and LODs. It was also found that housing segment has their own transcription guide for building components.

Guidelines for BIM activities in Business Premises segment are currently created and developed in some projects project-specific, but the data is not provided and shared yet generally among projects or employees. Thus, it could be stated that BIM activities are at development phase and instructions will be probably created later for wider use among projects. However, good development directions and efforts can be seen from the activities within the company related to this issue.

Summary of data search

In summary, general guidelines and instructions about different processes exists, but more deeper describing about implementation of different processes is needed. Both departments, design management and procurement, have their own guidelines and instructions for the processes but there is not much guidance on the interfaces between them. Some description

of the supply chain process between design management and procurement would be needed. The design schedule is encouraged to be done for the project and there is a lot of discussion about design packages and procurement packages. Also, inspections about plans and procurement plan are considered. Nevertheless, the process has not been properly defined or explained in the guidelines or instructions. At the moment, the design packages and procurement packages are separate entities in the company's instructions and their connection is not expressed. Design packages must be designed to support procurement packages and production. It is important that properly resource allocation is done already at the beginning of the project when designing work has not been started and project is being planned. Collaboration between design management, procurement and production is mentioned in some process cards and guidelines, but the ways to collaborate is not provided or explained properly.

3.2 Interviews

Interviews were constructed based on literature review, data search from company's databases, internal meetings with thesis advisor and company's management as well as understanding of the problem. The purpose of interviews was to investigate company's present practices related to the supply chain process between design management and procurement, and as well discover the challenges related to the subject and possibly find out or receive development proposals from the interviewees. A frame for interview questions was formed and interview questions were created by the author. The interview questions were designed so that the scope was not to guide the interviewees to the answer and all questions were commented by company's few employees and thesis advisor, which were from their title a procurement manager, a head of developer contracting, a procurement engineer and a project engineer, before starting interview phase. All these people were excluded from the interviews.

The interview frame was divided into questions related to interviewee's background, company's present practices, challenges and problems as well as development propositions. Interviews were conducted anonymously in Finnish, and they were recorded in the interview sessions. Later recorded interviews were analyzed and translated into English by the author, and only author utilized and listened them before deleting them. Permission for recording was asked from every interviewee. The interviewees were selected beforehand from different departments in the meeting with company's advisor, procurement manager and head of developer contracting, and they were contacted by the author. All interviews were voluntary and there was the opportunity to refuse. Interviewees were from procurement department, design management department, development department and production department. 20 employees were interviewed during interview phase and Table 6 shows job title, department and experience on topic of interviewees and interview times of interviews.

The final interview frame and questions are presented in Appendix 2.

Table 6. Information about interviews

Interview number	Job title	Department	Experience on topic	Interview time
INTVW 1	Procurement Engineer	Procurement	Several years and different projects	52 min 5 sec
INTVW 2	Site Engineer	Design management / Production	About 1,5 years	57 min 47 sec
INTVW 3	Procurement Engineer	Procurement	Several years (about 17 years)	35 min 43 sec
INTVW 4	Project Engineer	Development / Design management	2 years	41 min 30 sec
INTVW 5	Procurement Manager	Procurement	Several years (about 20 + 8 years)	37 min 9 sec
INTVW 6	Project Manager	Design management	About 10 years	55 min 29 sec
INTVW 7	Procurement Engineer	Procurement	Several years	40 min 6 sec
INTVW 8	Project Manager	Design management	Several years and different projects	1 h 5 min 49 sec
INTVW 9	Production Engineer	Design management / Procurement / Production	Few years and different projects	51 min 23 sec
INTVW 10	Head of Business Development	Business development	Very strong background from different projects	48 min 9 sec
INTVW 11	Project Manager	Design management	About 12 years	1 h 2 min 6 sec
INTVW 12	Project Engineer	Design management	About 7 + 2 years	51 min 25 sec
INTVW 13	Procurement Engineer	Procurement	About 8 years	59 min 55 sec
INTVW 14	Project Manager	Design management	Several years in different job titles and projects	1 h 37 sec
INTVW 15	Project Director	Production	Several years in different job titles relating to production	1 h 12 min 50 sec
INTVW 16	Project Manager	Design management	Several years in different job titles	59 min 8 sec
INTVW 17	Development Manager	Development	Supportive tasks for projects and performance development	1 h 1min
INTVW 18	Project Manager	Design management	Several years in different job titles and different projects	57 min 31 sec
INTVW 19	Procurement Manager	Procurement	About 9 years	51 min 9 sec
INTVW 20	BIM-VDC Development Manager	Development	About 13 years	52 min 4 sec

3.3 Analysis and results

The recorded interviews were analyzed and translated from Finnish into English afterwards by the Author because interviewing in English was considered not to be the best way to get properly answers and satisfying data. The answers to interview questions were written open from every interview and they are considered in the following analyses presented below.

Company's present practices

Existing policies and process between design management and procurement

Ten interviewees directly reported that there was no common process description or guidelines considering the supply chain process between design management and procurement. The rest of the interviewees suspected that there was none or did not know if there was. It was considered that there are loose processes for design management and procurement activities but clear holistic description of the whole process between design management and procurement is missing as design management and procurement function separately from each other. The need for a process description emerged during the interviews. The interviewees were also aware that they may have silos in departments and the process is case-specific at the moment as well there are few common processes and the project staff grabs the project itself and starts applying the practices considered to be the best. Activities were performed differently between different projects based on the habits experienced by the individuals as good.

It was recognized that different methods were used in different projects considering the process and there was no common method in use. For example, one method was that procurement packages had been used to control the design work and no separate design packages had been made. Another method tried was that the design package and procurement package models had been sometimes presented but clear procedures and instructions may not have existed. Third example was that design and procurement packages have been same package entities. Nevertheless, it was told that the whole chain process starts with making a general schedule for the construction and based on it a procurement plan and schedule are created and after these the design schedule is created. The design schedule is created with help of a procurement plan where the need times for the plans are specified and is drawn up in every project, but there are already differences in the meaning of that term that is, at what stage it is drawn up and on what basis. It would be important to harmonize practices and procedures so that the process does not overly vary in project implementation between different projects and be unclear. The supply chain process between design management and procurement is complicated enough already by its nature, thus it would be necessary to create a process description about it.

Some of the interviewees felt that procurement often comes too late aboard for the project planning and may not be early enough involved in the project to set schedules and more, in order that plans would be of the right level at the right time. From this it can be concluded that resource allocation is not working properly enough considering the project planning. Table 7 compiles discoveries and statements considering analysis about existing policies and process between design management and procurement.

Table 7. Existing policies and process between design management and procurement

Discoveries	Statements
There was no common process description or guidelines considering the supply chain process between design management and procurement.	(INTVW 2) *"The aim is to have common policies, but at the moment there is no common process"* (INTVW 4) *"There are loose processes for design management and procurement activities but there is no clear holistic description of the whole process between design management and procurement"* (INTVW 10) *"Process descriptions about design management and procurement are not synchronized and, in my view, design management and procurement function separately from each other"*
The need for a process description emerged.	(INTVW 8) "*There are no written common policies and there is a need for them and guidelines considering the supply chain process between design management and procurement, and a division of responsibility is also needed"*
Activities were performed differently between different projects based on the habits experienced by the individuals as good.	(INTVW 4) "*the process is not controlled and comprehensive, but based on the parties' own views"* (INTVW 6) *"there are probably as many ways to act now as there are project managers"*
It was recognized that different methods were used in different projects.	(INTVW 19) *"Procurement packages have been used to control the design work and no separate design packages have been made, however probably we should go in this direction that design packages would be used to control design work"* (INTVW 14) *"The design package and procurement package models have been sometimes presented but clear procedures and instructions may not have existed"* (INTVW 3) *"The design schedule, design packages and procurement schedule as well as procurement packages are used in the current project. Efforts have been made to make the procurement packages equate the design packages, and design package has been created based on procurement package."* (INTVW 8) *"There are not always separated design packages and procurement packages, but sometimes they are same package entities"*
Resource allocation is not working properly enough considering the project planning.	(INTVW 17) *"Procurement often comes too late aboard for the project planning"* (INTVW 10) *"Procurement may not be early enough involved in the project to set schedules and more, in order that plans would be of the right level at the right time. Sometimes too much planning has been done, thus you must go back in the design and do it twice"*

Creating the design schedule and its content as well as parties involved

There were many different methods to create the content of design schedule depending on whether the design packages were used or the procurement packages or some other titles, thus currently there are many different design schedule methods in use. Some of the interviewees considered that the aim is to have procurement packages in the design schedule and title distribution is similar to procurement package distribution in the design schedule. While some others thought that design packages should be created, and it would be the right development direction, and design packages and procurement packages have been used together in some projects, but not nearly always. It was mentioned as well that procurement packages have been used as information for design packages and thus design packages include afterwards procurement packages. In detailed design phase, design packages which are based on the need times for the plans of procurements have been sometimes used. It was notified that

the use of design packages has become more refined in lifecycle projects than in other projects yet. One alternative method for creating design schedule was expressed as creating three different level schedules to support each other including upper level schedule, procurement/drawing schedule and separated building frame phase schedule.

It was brought out that the design schedule should be created based on general schedule and procurement schedule, and it is necessary that all parties like production, procurement and design management are involved. Most of the interviewees thought that project manager creates the design schedule and procurement as well as production must be involved and consulted. Thirteen interviewees told already at this stage of the interview that the use of design packages in the design schedule should be taken into use more generally in projects. Table 8 compiles discoveries and statements considering analysis about creating the design schedule and its content as well as parties involved.

Table 8. Creating the design schedule and its content as well as parties involved

Discoveries	Statements
Currently there are many different design schedule methods in use.	*(INTVW 1) "The aim is to have procurement packages in the design schedule"* *(INTVW 3) "Title distribution is similar to procurement package distribution in the design schedule"* *(INTVW 4) "Design packages should be created, and it would be the right development direction"* *(INTVW 5) "Design packages and procurement packages have been used together in some projects, but not nearly always"*
The design schedule should be created based on general schedule and procurement schedule.	*(INTVW 20) "The design schedule should be created based on general schedule and procurement schedule, and it is necessary that all parties like production, procurement and design management are involved"*
Design management, procurement and production should be involved creating design schedule.	*(INTVW 18) "Project manager creates the design schedule and procurement as well as production must be involved and consulted"* *(INTVW 13) "But at worst, it has been done by one person from his/her point of view"*

Creating the procurement strategy and plan as well as parties involved

The procurement plan had been always created in projects, but creating or forming the procurement strategy was generally at weaker level or it hadn't been done at all. It was discovered also that procurement formats have not been considered enough at the beginning of the project before the start of production. Nevertheless, sometimes procurement formats have been pondered when considering certain procurement packages, for example, in case of production subassembly, the needed level for main designers planning has been taken into account and needed plans for procurement.

As regards creating the procurement strategy, it was mentioned that a procurement strategy should be made for the project at a fairly early stage and principles for procuring agreed as well as critical, urgent and economically significant procurements identified. The distribution of procurements must be formed, and procurement formats decided. One must know how to approach each procurement entity or package.

Generally, it was mentioned that procurement plan is created based on general schedule received from production and includes procurement packages. It presents the need times for plans, sending invitations for tenders, receiving tenders, awarding subcontracts and starting times for subcontract tasks. The links between design management, procurement and production were identified but the challenge, however, is that procurement is only one part of the supply chain of design management, procurement and production, thus linking between chains is important. It was discovered based on the interviews that procurement engineer creates procurement plan and schedule, and construction manager and sometimes project manager are involved, thus the point of view of production and design management must be included. Table 9 compiles discoveries and statements considering analysis about creating the procurement strategy and plan as well as parties involved.

Table 9. Creating the procurement strategy and plan as well as parties involved

Discoveries	Statements
The procurement plan had been always created in projects but creating or forming the procurement strategy was generally at weaker level.	*(INTVW 1) "A proper procurement strategy has not always been done, however luckily it is now being done in our new project. Procurement packages will be created for the procurement plan and strategy for forming procurement packages is being done in this project"* *(INTVW 4) "The procurement strategy is not made even though it should be made in the early stages, and individual decisions are made but the contents of the packages are not holistically reviewed as they should. Again, only the individual's way of doing is emphasized and there is no process of how to do it"*
Procurement formats have not been considered enough at the beginning of the project.	*(INTVW 10) "Procurement formats have not been considered enough at the beginning of the project before the start of production, by whom have design responsibilities and do suppliers have also"*
Procurement strategy should be made at a fairly early stage and principles for procuring agreed as well as critical, urgent and economically significant procurements identified.	*(INTVW 6) "Basically, a procurement strategy is made for the project at a fairly early stage and principles for procuring are agreed as well as critical, urgent and economically significant procurements are identified. The distribution of procurements must be formed, and procurement formats decided, for example in case of production subassembly"* *(INTVW 13) "The work begins with the fact that the procurement strategy is considered in every part of the whole, whether it is made on paper clean is not always done, but it has been gone through with construction manager and with the person in charge of design management. You need to know how to approach each procurement entity or package"*

Coordination or cross checking of design schedule, design packages and procurement packages

Two different views emerged in the interviews on this issue. Nine interviewees reported that no coordination or cross checking of design schedule, design packages and procurement packages has been made or coordination has not been made properly. Couple interviewees didn't know, and eight interviewees reported that coordination has been made at some level, nevertheless some of them had not used design packages and procurement packages but had managed design work on a pure procurement basis. Design schedule and procurement schedule had been combined into same schedule at one project and in some projects the design packages had been created based on distribution of procurements (procurement packages), thus an effort has been made to have content as parallel as possible. Coordination or cross

checking is probably the biggest problem currently. However, some suggestions were already discovered that parties shall prepare preliminary design and procurement schedules themselves and afterwards collaborate and coordinate schedules and packages. Table 10 compiles discoveries and statements considering analysis about coordination or cross checking of design schedule, design packages and procurement packages.

Table 10. Coordination or cross checking of design schedule, design packages and procurement packages

Discoveries	Statements
No coordination or cross checking of design schedule, design packages and procurement packages had been made or coordination had not been made properly.	*(INTVW 1) "The intention is that the design packages contain the documents required by the procurement packages", (INTVW 2) "nevertheless, the design packages and procurement packages have been used separately and there is no coordination or cross checking made"*
When design work had been managed on a pure procurement basis, it had led to problems.	*(INTVW 16) "The procurement packages have been also used as design titles in the design schedule and therefore there have sometimes been conflicts between design and procurement priorities. For example, the relationship with building services engineering (HVAC and electrical engineering) and ceiling subcontract, when suspended ceiling procurement is not so urgent or rushed but building services engineering is in a hurry, thus the structures for the suspended ceiling would have to be designed ready in case of that"*
Coordination or cross checking is probably the biggest problem currently.	*(INTVW 11) "This is probably the biggest problem right now, because it requires a lot of work and is complex entity and things have to be linked together and blown up into smaller pieces. Determining design packages and procurement packages requires skillful resources early in the project and identifying ulterior things and making decisions. Critical procurements should be identified and determine. The difficulty is that not all the necessary information may yet be available, and one does not want to create semi-finished schedules well in advance, in order that they do not look bad later in someone's opinion. Nevertheless, the procurement package is a customer for the design package and must define its own content and requirements"*
It was suggested that parties shall prepare preliminary design and procurement schedules themselves and afterwards collaborate and coordinate schedules and packages.	*(INTVW 18) "The parties shall prepare and make preliminary design and procurement schedules themselves. After that they gather together and check if they are cohesive and parallel and make the necessary changes together. Reviews or inspections of packages should be also kept later with designers involved in order to guarantee a realistic plan for the entity. Nevertheless, a unified view within own company is essential before involving designers"*

Information, guidelines, instructions, or tools needed which did not exist

It was brought out that a bold alignment from upper management is needed to start promoting certain kind of policy considering whether to decide that company starts using design packages and procurement packages generally. One must also commit to the process that is agreed to be used, otherwise it is pointless to create a process that is not followed. Eleven interviewees directly expressed that there is a need for a process description of the supply chain and operating procedures as well as policy whether design packages and procurement packages are used. Also, a description of the responsibilities of the roles should be written down and a unified approach should be standardized.

It was mentioned considering forming design packages that procurement package cards should be utilized in forming design packages which would help the forming process as they would include necessary information about the content of the procurement package. Procurement packages could be also standardized for certain repetitive building components and distribution of procurement could be later modified project specific. One another observation was that guidance and information are difficult to find at the moment from the target company's databases, which supports the author's data search from company's databases. Also, a new scheduling program for the company is sorely needed according to the interviewed and last consideration was that perhaps a standard design schedule template would be needed which involves design packages and could be modified project specific. Table 11 compiles discoveries and statements considering analysis about information, guidelines, instructions, or tools needed which did not exist.

Table 11. Information, guidelines, instructions, or tools needed which did not exist

Discoveries	Statements
A bold alignment from upper management is needed to start promoting certain kind of policy.	*(INTVW 2) "A bold alignment from upper management is needed to start promoting certain kind of policy, it is easier to develop if there is something on which to develop (recognizing things that do not work)"* *(INTVW 5) "One must commit to the process that is agreed to be used"*
Procurement package cards should be utilized in forming design packages, and procurement packages could be standardized for certain repetitive building components.	*(INTVW 4) "Procurement package cards should be utilized in forming design packages"* *(INTVW 20) "Standard titles for procurement packages would be good and the same nomenclature would always go through the whole chain up to production. It would be easy to keep track of what quantity information has been in the past and how it is changed after awarding the subcontract"*
Guidance and information are difficult to find at the moment from the target company's databases.	*(INTVW 6) "Guidance in databases is not easy to find but information is difficult to find at the moment and it is scattered in different places"* *(INTVW 10) "Functions have been described by department as separate functions previously in databases"*

Standardized levels of development considering building information modeling

Standardized levels of development for building information modeling does not exist currently according to ten interviewees, and others did not know if they exist, but they are in a development process at the moment. It was found that in the master plan design phase, it is possible to carry out a rougher design on common building information modeling requirements' level of developments which are refined to more accurate levels into the detailed design phase but currently there is no stage in the supply chain where it has been verified that one has designed according to the required levels of development, thus it would be necessary that someone would be responsible for this issue and would do the verifying during the design work. It was mentioned that there would be a need for standardization of information structure and content in general in Finland, which could be to rely on in a design contract. Finland lacks such and therefore the level of modeling is often bad in Finland and leads to a variation in the type and level of building information models in different projects. Nevertheless, it was discovered during the interviewing that some projects have developed

project-specific instructions for building information modeling and determined levels of development, but it has been challenging.

Almost all of the interviewees found standardizing levels of development useful. The biggest benefits identified were getting quantities out of the model for procurement, provided they could be trusted, and using the model to illustrate contract boundaries in the negotiations. However, the company has transcription for quantity takeoff in the Housing segment and based on that Business Premises segment is going to make its own transcription for quantity takeoff. Table 12 compiles discoveries and statements considering analysis about standardized levels of development considering building information modeling.

Table 12. Standardized levels of development considering building information modeling

Discoveries	Statements
Standardized levels of development for building information modeling does not exist currently in the Business Premises segment.	*(INTVW 20) "These are currently being prepared for the Business Premises segment because the current operating model and common building information modeling requirements' levels of development do not directly help this issue with design management. However, on the housing segment side, levels of development have been standardized already. The information designation and naming conventions for the information model should be agreed properly with designers in order that data could be standardized for building components and examination over projects would be enabled"*
In the master plan design phase, it is possible to carry out a rougher design on common building information modeling requirements' level of developments which are refined to more accurate levels into the detailed design phase.	*(INTVW 20) "In the master plan design phase, it is possible to carry out a rougher design on common building information modeling requirements' level of developments which are refined to more accurate levels into the detailed design phase. Unfortunately, at the moment there is no stage in the supply chain where it has been verified that one has acted or de-signed according to the required levels of development"*
There would be a need for standardization of information structure and content in general in Finland, which could be to rely on in a design contract.	*(INTVW 20) "There would be a need for standardization of information structure and content in general in Finland, which could be to rely on in a design contract. Finland lacks such and therefore the level of modeling is often bad in Finland"* *(INTVW 13) "In practice, there are no standardized levels of development, but even for persons that make design contracts it is not clear what levels of development means and for what they are used. This leads to a variation in the type and level of information models in different projects"*
The biggest benefits identified were getting quantities out of the model for procurement, provided they could be trusted, and using the model to illustrate contract boundaries in the negotiations.	*(INTVW 8) "It would be very useful, in order to be able to include required BIM levels of development into design contracts and procurement would get decent quantities for procurements"* *(INTVW 10) "Using the building information model would be very useful, but first we need to be able to define what do we want from the building information model and that requires the participation of several people"* *(INTVW 17) "It would be useful also for designers to know what levels of development is required with each building component when designing and building information modeling"*

Whether the design work is managed currently by building information modeling

There were a lot of variation between the answer whether the design work is managed currently by BIM in design management or not. Nevertheless, during the interviews, it emerged that BIM coordinator would be needed to support design management when considering BIM based design management work. Design management is so demanding, and involves many dimensions, that insisting and monitoring levels of development in the model requires a dedicated person to support design management according to interviewees. Whether the design work is done via building information modeling varied a lot also. Nevertheless, currently the design work is mainly done by building information modeling depending on the skills of design company and designers. The problem is that it is very challenging to utilize building information models properly in procurement without standardized levels of development by each building component. Table 13 compiles discoveries and statements considering analysis about whether the design work is managed currently by building information modeling.

Table 13. Whether the design work is managed currently by building information modeling

Discoveries	Statements
There were a lot of variation between the answer whether the design work is managed currently by BIM in design management or not.	*(INTVW 20) "The design work is not managed properly by building information modeling"* *(INTVW 15) "Design management is not based on building information modeling"* *(INTVW 10) "It depends entirely on the project manager and the variation is big"* *(INTVW 11) "The design work is maybe still only slightly managed by building information modeling, but somewhat yes"*
Whether the design work is done via building information modeling varied a lot also.	*(INTVW 8) "It varies from design company, but big companies design almost everything by building information modeling. Some details are still done with the 2D drawing and some of the HVAC design before architect model is advanced enough"* *(INTVW 10) "The model is used to perform collision examinations and coordination between different design fields. The level of expertise of design agencies also influences whether or not they have BIM as the number one tool in design work"*

Availability of design documents and plans for the procurement currently considering time and content

It was discovered that it is very usual that plans are not generally supplied by the designers to the procurement at right time with right content as agreed earlier. There is a need for proper determination of what is the required level of plans for the procurement, ergo, a common view about this should be developed. One reason for the delays of plans was found, for example, it easily becomes dominant way that plans are promised and not taken seriously, and even the procurement no longer insists the right level of plans halfway through the project. Diving into this should know how to stop properly. It is important that this kind of habit is not allowed to continue.

According to many interviewed, buffers are used extensively in the supply of plans for the procurement because at the moment one cannot rely at all on designers to supply plans for the procurement at right time. It was suggested that transparency between the parties would

be important for the parties to know the right deadlines and they would not learn that everything has a buffer. It was discovered that partly delays in supplying plans for the procurement occurs because of the inability of design management and procurement to describe what level of plans are needed. The procurement must be involved in influencing design management and be active as well as express what plans and what levels are needed. The supplying of plans for the procurement have been tried to be controlled with various inspections or reviews about the plans but nevertheless these have been accomplished too little and it would be extremely good way to keep such reviews together with designers and procurement. Lastly, it was stated that managing the supplying of plans requires extremely hard control, and the design management and the procurement should continuously interact considering procurements and design management so that the design management and the procurement work as a supply chain. Connecting the procurement strategy to the chain is still a challenge, which requires in particular tight continuous interaction and implementation of the process. Table 14 compiles discoveries and statements considering analysis about availability of design documents and plans for the procurement currently considering time and content.

Table 14. Availability of design documents and plans for the procurement currently considering time and content

Discoveries	Statements
It is very usual that plans are not generally supplied by the designers to the procurement at right time as agreed earlier.	*(INTVW 13) "Without lying, almost 100% of the plans do not come when agreed. It is more the practice that they are late or if they arrive on time, they are too weak from their level or some plans are missing"*
It easily becomes dominant way that plans are promised and not taken seriously.	*(INTVW 13) "If the focus of the design is elsewhere, it is usually compromised from plans to be provided for the procurement if other planning is urgent for example production and plans related to permissions, and agreed things begin to be delayed on a regular basis. It easily becomes dominant way that plans are promised and not taken seriously, and even the procurement no longer insists the right level of plans halfway through the project but the approach is so that can one deliver at least something, thus I will compose the rest of it"*
Buffers are used extensively in the supply of plans for the procurement.	*(INTVW 19) "To put it bluntly, at the moment you cannot rely at all on designers to supply plans for the procurement. There is always the design schedule, but the plans are mainly either late, wrong at their level or bad at every project. Buffers are used often in the delivery schedule of plans due to the supply chain process cannot be trusted"*

Summary about company's present practices

Based on the interviews it was discovered that there is no common process description or guidelines considering the supply chain process between design management and procurement. Design management and procurement function separately from each other currently and different methods are used between the projects, thus there is a need for common policies and process description. Procurement comes often late aboard for the project planning and resource allocation should be at an adequate level already during project pre-planning. There were different methods to create design schedule whether the design packages were used or the procurement packages or even some other task titles in the design schedule.

Most of the interviewees thought that using the design packages with the procurement packages would be the right development direction to control the supply chain process between design management and procurement. Nevertheless, also other opinions existed. One common thing was brought out and it stated that the design schedule should be created based on general schedule and procurement schedule, when considering detailed design phase's design schedule, to serve procurement and finally production at site. Procurement plan had been always created for every project but creating the procurement strategy for procurement packages was generally at weaker level. Critical, urgent and economically significant procurements should be identified, and procurement formats should be decided for every procurement in the distribution of procurements. It is necessary to know how to approach each procurement entity with a common understanding between design management and procurement.

There were two different views about whether coordination or cross checking of design schedule, design packages and procurement packages had been done or not. Half of the interviewees reported that design packages and procurement packages have been used separately and no coordination or cross checking has been made. Nevertheless, some interviewees told that efforts have been made to have the content of design packages and procurement packages as parallel as possible. It was stated by one of the interviewees that coordination of design and procurement packages is probably the biggest problem right now because it is complex entity and things have to be linked together, and it requires a lot of work and skillful resources early in the project. Procurement package is a customer for the design package, thus defining well its own content will help the coordination work of all packages and understanding of the entity. It was discussed with one of the interviewees that coordination work should be done in collaboration so that the parties shall prepare and make preliminary design and procurement schedules including design and procurement packages themselves, and afterwards gather together and check if they are cohesive and parallel as well as make the necessary changes together. A bold alignment from upper management would be needed to start promoting certain kind of policy with this issue between design management and procurement. If the design packages and the procurement packages are chosen to be utilized in the projects, they could be standardized to some extent.

Standardized levels of development for building information modeling building components are being currently developed and prepared for the Business Premises segment. Nevertheless, on the Housing segment standardization has been already done because of the repetitive nature of housing construction. Almost all of the interviewees found standardizing useful and the biggest benefits could be getting quantities out of the model for procurement and using the model to illustrate contract boundaries. The company has transcription in use for quantity takeoff in BIM in Housing segment and Business Premises segment is going to make its own transcription for use. There is currently a lot of variation whether the design work is managed by BIM in design management or not. It depends entirely on the project manager but in the big picture the design work is maybe still only slightly managed by BIM. It was discovered that design management needs a BIM coordinator to support the work of design management and monitor levels of development in the model because pure design management is so demanding itself and involves many dimensions. Currently, the design work is mainly done by building information modeling depending on the skills of designers and companies.

At the moment, a lot of buffers are used in the supplying of plans for the procurement because almost all interviewees stated that the plans are often mainly either late, wrong at their level or bad at every project. It was recognized that there is a need for proper determination of what is the required level of plans for the procurement to help designers' work and the company's procurement should be able to express it. Also, transparency between the parties could help to prevent unnecessary waste from buffers and motivate designers to deliver the agreed plans on time for the procurement.

It was as well discovered during the interviews that some projects have made a project-specific project plan where the responsibilities of all parties have been brought out and the special features of the project have been presented. The project plan has usually described issues considering organizations, schedule control, cost control, design management, procurement, quality control, risks and their control, environment and safety plans, exchange of information and project completion. In certain project plans investigated by the author, there is described that the owner demands that design schedule must be made by the prime contractor including design packages while procurement packages are formed as well for procurement plan and prime contractor is responsible for design management.

The last discovery was that company's project managers have a common external database where they are developing things relating to the design management, but currently they have not released or finished any instructions about supply chain between design management and procurement. Thus, things are being developed further, but there is no knowledge at what level and how development work is being done. Whether the procurement and the production are involved in development work or not.

Challenges and problems

Current challenges and problems between design management and procurement

The first problem is that there is no common process between design management and procurement, and it would be needed. It was told that the whole process should be understood as a chain from start to finish and managed making sure that interfaces work. The practical problem is that such large entities are formed and lots of dependencies making things difficult to manage. Another big problem is that, since the process does not exist, there is also no common understanding between the design management and the procurement of what plans and what level of plans are needed for each procurement. Twelve interviewees indicated the existence of this problem. It was discovered that things are not done together as everyone does their part separately and interfaces are not defined early enough. Ergo, the level required for the procurement is not defined for the plans or the procurement format is not determined. On the other hand, the production does not provide a clear enough defined schedule about when procurements are needed.

It was mentioned several times that the procurement should list what plans and documents are needed for the procurement package and what level of planning is required. This would help the design management to form the contents of design packages and the designers to know the required level of plans. It was as well stated during the interviews that sometimes design management and procurement have just their own schedules which are not synchronized properly to work together. One other common concern was the lack of resources and

time to plan the project properly before starting to order design work. Also, the procurement would be needed to be involved earlier in project planning. Finally, the supply chain process between design management and procurement is also influenced by the decision making of the owner or the user, which brings challenges to implementing the process properly. Table 15 compiles discoveries and statements considering analysis about current challenges and problems between design management and procurement.

Table 15. Current challenges and problems between design management and procurement

Discoveries	Statements
There is no common process between design management and procurement, and it would be needed.	*(INTVW 2) "There is no common process between design management and procurement, and it would be needed. If every time a new project starts to rethink operating methods and processes, it is difficult to find the right development direction. The database doesn't support daily work currently and no information or guidance is available on the subject"* *(INTVW 4) "The company's common policies and processes are not clear or defined"* *(INTVW 9) "Sometimes the whole process is wasted, a clear process is needed on how to act in the process between design management and procurement. The management process is not always systematic enough. The common process description is needed on paper"*
There is no common understanding between the design management and the procurement of what plans and what level of plans are needed for each procurement.	*(INTVW 1) "The design management and the procurement don't always have a common understanding of what plans are needed at some point"* *(INTVW 4) "There is a lack of common understanding between the two parties on what level of planning is sufficient in each phase"* *(INTVW 18) "There should be a unified view of what level of plans are required for the procurement. In some procurements, it is wanted that plans are developed by using alternative solutions provided by subcontractors and the procurement should also understand such a thing"* *(INTVW 15) "I would expect from the procurement that some plans could be applied for searching different design options and solutions"*
The procurement should list what plans and documents are needed for the procurement package and what level of planning is required.	*(INTVW 15) "Designers don't understand what plans are required for the procurement package. A separate listing is needed of what plans and documents are required for the package including what level of planning is required"*
There is a lack of resources and time to plan the project as well as the procurement would be needed to be involved earlier in project planning.	*(INTVW 11) "For one reason or another, the procurement is not early enough involved in the project. I don't know if it is not being understood to resource it early enough or perceiving it as a cost, or somehow not yet up-to-date or not understanding the value and need for work in the early stages. Maybe it is difficult to do the job when there is nothing yet done"*
The supply chain process between design management and procurement is also influenced by the decision making of the owner or the user, which brings challenges to implementing the process properly.	*(INTVW 6) "The biggest problems are in the owner's decision making relating to the plans which the procurement needs from the designers. The ultimate user or owner has changed their minds too late or too many times, or they are pursuing the moon from the sky, meaning their money is sufficient for a cheaper entity but the best and most expensive entity is desired. This complicates the decision-making process because anything for which the money is sufficient will not satisfy the customer. The customer is given options and saving suggestions and recommendations. Nevertheless, in the end, the customer cannot be forced to make a decision and sometimes it is difficult to find any solution that would satisfy any party. There are often too high expectations*

	from the budget, or the customer has slight technical know-how, thus the solution pursued may not even exist"

Waste in the process between design management and procurement

It was commented several times that generating and delivering plans that are unsuitable for the procurement is a huge waste in the chain between design management and procurement. It was suggested that the desired level of plans should be determined for the procurement package in order that designers will not draw plans too rough or too advanced and the required level depends on procurement format. Many of the interviews reported that waste occurs when the procurement must wait plans from designers to be delivered when plans are either already late from the deadline or they are incomplete and must be corrected. A solution suggested for preventing this kind of waiting was that inspections or reviews about the plans would be kept together properly early enough before the procurement needs the plans. However, this would require that both parties and designers should take a part in these meetings. Also, if the designers focus on the wrong things, waste is produced in the process. Critical procurements must be identified, and design management has to inform designers what things are crucial priorities. Another waste was found instructing that it is a waste that every project has to create a new way of working at the beginning of the project or create a project's way to work between design management and procurement because there is no common process description about it to rely on. It was recognized also that decisions taken too late by the customer can result in waste for the procurement in the project when there is not enough time for procuring and cost savings are not possible due to overly urgent procurements. Lastly, one of the interviewees mentioned as well that the use of buffers both in design schedule and procurement schedule generates waste when one cannot trust on plans coming in on time. Table 16 compiles discoveries and statements considering analysis about waste in the process between design management and procurement.

Table 16. Waste in the process between design management and procurement

Discoveries	Statements
Generating and delivering plans that are unsuitable for the procurement is a huge waste in the chain between design management and procurement.	*(INTVW 20) "Generating and delivering plans that are unsuitable for the procurement is a huge waste in the chain between design management and procurement"* *(INTVW 11) "Waste occurs when the needs of procurement packages are not properly defined, and they are discussed when there is a lot of design work already done. Plans are drawn either at too detailed level or too rough level"* *(INTVW 1) "Waste occurs if designers plan too far until it is decided that a certain procurement package will be procured as a production subassembly. One must save designers' time by deciding production subassembly procurements on time"*
Waste occurs when the procurement must wait plans from designers to be supplied when plans are either already late from the deadline or they are incomplete and must be corrected.	*(INTVW 5) "Lack of co-operation between design management and procurement results in wasted design work when planning must be done again, or plans must be fixed, and the procurement waits plans"* *(INTVW 15) "It is important that design management correctly prioritizes and monitors design work during production and ensures that focus is on the right things at the right time"*

Every project has to create a new way of working at the beginning of the project or create a project's way to work between design management and procurement because there is no common process description.	*(INTVW 5) "It is a waste that every project has to create a new way of working at the beginning of the project or create a project's way to work between design management and procurement because there is no common process description about it to rely on"*
Decisions taken too late by the customer can result in waste for the procurement in the project.	*(INTVW 14) "Decisions taken too late by the customer can result in waste for the procurement in the project when there is not enough time for procuring and cost savings are not possible due to overly urgent procurements. Late decisions have also side effect on price"* *(INTVW 19) "The procurement must often send invitation for tenders with incomplete plans and these plans will be replenished already in a week, thus tenders are recalculated many times in a tendering round"*

Whether the design packages and procurement packages are synchronized

At this point, there were differences in the answers depending on whether the design and procurement packages had been used at all or whether the design had been managed by procurement basis. Some of the interviewees had been using similar packages in the design schedule and procurement plan, thus it is a different thing than synchronizing the design and procurement packages, and it was noticed that it doesn't work properly from the design perspective because designing cannot be done always in the same order as procurements. Nevertheless, some individual projects had been trying to use the design and procurement packages.

There is a lack of coordination of design and procurement packages and they are not synchronized properly. Nevertheless, there have been attempts, but changes and refinements to packages and schedules have occurred, and no updates to coordination and synchronization of packages have been done. Thus, it is very necessary that if any changes occur, the synchronization will be done again based on these changes. Based on interviews, it can be concluded that design packages and procurement packages are not properly synchronized in projects and it would be essential to provide aligned and sensible entities. Table 17 compiles discoveries and statements considering analysis about whether the design packages and procurement packages are synchronized.

Table 17. Whether the design packages and procurement packages are synchronized

Discoveries	Statements
There is a lack of coordination of design and procurement packages and they are not synchronized properly. Nevertheless, there have been attempts.	(INTVW 2) "They have been treated as separate entities and there is a lack of coordination. Maybe people are not used to think that they should be coordinated" (INTVW 4) "There has always been an effort to combine the needs of procurement and production that what plans are needed. However, there have not always been decent packages to be reviewed because plans have been requested in a hurry disorderly from the designers" (INTVW 6) "The design packages and procurement packages have been aimed to be synchronized", (INTVW 18) "but it would require more specific action and work together in this regard"

	(INTVW 13) "Yes, this has usually been attempted and after that there have been changes and no updates have been made even if it was very necessary" and (INTVW 12) "changes and refinements to design and procurement will also cause changes to this synchronized entity"

Current position with the subject, and the aim

It was reported that there is no process and there is a need for an outline of what to do. A review about the design packages and the procurement packages together with design management and procurement is needed, and related documents must be updated as the project progresses if changes occur. Creating a procurement strategy should be mandatory for every project and forming the design and procurement packages as well as defining procurement formats and level of planning for each procurement package. Interviewees longed for a unified process and thought that the design packages and procurement packages should be created separately and afterwards coordinated. When pre-planning is in order, it will serve everything later according to interviewees. Table 18 compiles discoveries and statements considering analysis about current position with the subject, and the aim.

Table 18. Current position with the subject, and the aim

Discoveries	Statements
There is no process and there is a need for an outline of what to do.	*(INTVW 8) "Projects work differently, thus there is a need for guidance on the process of design management and procurement"* *(INTVW 5) "It would be good to define a clear process between design management and procurement, but commitment to that is also very important"*
Creating a procurement strategy should be mandatory for every project and forming the design and procurement packages as well as defining procurement formats and level of planning for each procurement package.	*(INTVW 4) "Much interaction is needed. Creating a procurement strategy should be mandatory for every project and forming the design and procurement packages as well as choosing procurement formats and determining level of planning for each procurement package"*
A unified process is needed, and the design packages and procurement packages should be created separately, and afterwards coordinated.	*(INTVW 10) "Design management, procurement and production should jointly inspect the connection between design packages and procurement packages. Changes and recurrences regarding design schedule and packages as well as procurement schedule and packages and production should be viewed in such a way that these packages and schedules are synchronized again"* *(INTVW 13) "The success of this is quite variable at the moment, we should get it more standardized how the design schedule is presented and what is the distribution of packages. The distribution of procurements is relatively constant, but the procurement must also be able to communicate its needs properly for design management"*

Summary about challenges and problems

It was discovered based on the interviews that the key problem is that there is no common process existing between design management and procurement. A common process description would be needed and the whole process should be understood and managed as a chain

from start to finish making sure that interfaces work. The second huge problem is that as there is no process existing, there is also no common understanding between design management and procurement about what plans and what level of designing is needed for each procurement entity. Common understanding of the strategy for each procurement package should be found in collaboration. Otherwise, it is likely that the entire complex project will fail, and designers supply the procurement with incomplete or wrong kind of plans or plans are delivered late for the procurement. It was brought out that the procurement should list what plans and documents are needed for the procurement package and what level of planning is required to help design management's and designers' work. It is important that design management and procurement synchronize their schedules and packages, and sufficient resources and time are allocated for the pre-planning of the project before starting to order design work. Also, the supply chain process is influenced by the decision making of the owner or the user, and it brings challenges for implementing the process properly.

The interviewees recognized that waste occurs when the needs of procurement packages are not properly defined, and plans are drawn either too detailed level or too rough level. In general waste occurs always when the procurement must wait for plans that are late or incomplete plans must be corrected. A solution for this was suggested that reviews about the plans would be kept together properly early enough before the procurement needs the plans. These kinds of meetings would also ensure that designers' focus is on right things. Decisions taken too late by the customer were also found as generating waste in the process and same thing was with the use of unnecessary buffers in the design and procurement schedules when one cannot trust on plans coming in on time.

The design packages and procurement packages are not synchronized at the moment. They have been treated generally as separate entities and there is a lack of coordination. Nevertheless, efforts have been made in some individual projects to synchronize packages, but it would require more specific action and work together. Also, reacting to changes in the project is necessary when considering the synchronization of design packages and procurement packages. Synchronization must be done again and updated if significant changes occur in the project.

Development propositions

The process by which design management can produce plans for procurement at right time

The first thing emerged was that the process should be described between design management and procurement. Most of the interviewees thought that using design packages and procurement packages would be the right process to start developing activities. It was suggested that the design packages and the procurement packages as well schedules will first be prepared separately by both parties and then their compatibility is investigated, and finally they are coordinated in collaboration. It was also brought out that the design packages and the procurement packages -process would be good when the procurement would report what plans are needed for the packages and the person responsible for design management would actively control the planning. It was recognized that there has to be a change in the culture of operations. The design management and the procurement must collaborate and have common understanding and goals about things in order to success with the supply chain process.

It also has an influence on the whole chain process because production depends on the success of these previous chain members, thus the point of view of production must be included in procurements and design management. Interaction between design management and procurement as well as between all parties was considered very important by the interviewees.

Interviewees expressed that pre-planning needs to be invested, creating the conditions for production to succeed and one must have a proper design schedule set up to serve procurement and production execution. It was stated that it would be good to have a separate list of what plans and documents are needed for the procurement package from designers, and also what level of planning is required. The interviewees identified also that when a procurement plan is made, the procurement formats must already be planned together with design management. A common understanding about procurement formats between design management and procurement is essential considering the whole project execution.

Many of the interviewees instructed that Last Planner system could be used in the design meetings in order to stay on schedule in terms of design. Also, the expertise of project manager was emphasized. The planning should be well managed, and enough designer resources are needed. The design packages must be properly and carefully instructed for the designers by the design management. The design schedule and packages shall be attached to the progress payments to be paid for the design companies.

It was noticed that many of the interviewees proposed that reviews about the plans for procurement packages must be held before delivering the plans for the procurement. Preliminary reviews of plans should be kept, and the level of plans should be verified before as plans reach the procurement. It was also suggested that design package inspections should be held between design management and procurement always before starting the next one of the design packages. Finally, it was mentioned that design packages and procurement packages could be standardized where applicable, thus it would be useful to create standardized design packages and procurement packages in order that operations would be less complex. Table 19 compiles discoveries and statements considering analysis about the process by which design management can produce plans for procurement at right time.

Table 19. The process by which design management can produce plans for procurement at right time

Discoveries	Statements
The process should be described between design management and procurement.	*(INTVW 18) "The whole process would have to be explicitly described, combining a design schedule and procurement schedule process"* *(INTVW 2) "The SUKE-model idea should start to be promoted and the principles of open building"*
Most of the interviewees thought that using design packages and procurement packages would be the right process to start developing activities.	*(INTVW 13) "The design package and procurement package -model is without a doubt exactly the right direction that we should go. It would clarify the design management from our point of view and hopefully also from the designers' point of view"* *(INTVW 14) "The linkage of procurements to design packages is absolutely essential"*
The design management and the procurement must collaborate and have common understanding and goals about things in order to	(INTVW 20) "There has to be a change in the culture of operations and there must be common goals for things" (INTVW 11) "Interaction on these issues is crucial to the whole issue" (INTVW 17) "Various parties must cooperate and be involved in planning a design and procurement schedules and packages. The owner and designers

success with the supply chain process.	should be also consulted to tell their views about issues. Openness and a culture of problem-solving would promote all activities and problem-solving in time" (INTVW 6) "Interaction between designers and design management is important especially if problems occur. Problems are reported and discussed in a timely manner to respond and coordinate changes. Designers and design management should aim together for the same goal that serves both procurement and production later"
Pre-planning needs to be invested, creating the conditions for production to succeed and one must have a proper design schedule set up to serve procurement and production execution.	(INTVW 1) "We need to change the process so that project organization is created in time and focus should be more on critical procurements when considering design work" (INTVW 4) "A procurement strategy and procurement plan should be created, and design packages then scheduled" (INTVW 8) "Critical procurements should be identified" and (INTVW 9) "the contents of the procurement package should be opened into required plans and documents"
The design schedule and packages shall be attached to the progress payments to be paid for the design companies.	(INTVW 8) "The design schedule and packages must be tied to the money and the payment program in order for it motivate designers to submit drawings on time for the procurement. However, incomplete plans are not eligible for payment even if delivered for the procurement"

Plans required by the procurement to be able to make proper invitations for tenders

It was discovered that there was a different understanding and opinions about what kind of plans the procurement needed. Thus, already in this case, a common understanding does not exist. Some of the interviewees thought that it would be best to have detailed design level plans and others thought that it depends on procurement strategy and formats. This is where the emphasis is on creating a procurement strategy and consensus on how to procure. In general, the objectives of the procurement in company-wide operations. A common understanding is needed. Do we purchase or procure? In the author's opinion, the procurement should also look for alternative solutions to the plans from the subcontractors and not just always buy everything directly with detailed designs. It is also intended to help design management to develop plans for desired procurement entities and find more cost-effective solutions or achieve cost savings. It can be decided in the procurement strategy that which procurement entities are desired to procure with possible alternative solutions, and which will be procured as production subassemblies as well as which are then purchased directly with detailed design level plans. From this it can be concluded that the level of planning required by the procurement strategy and format is required for each procurement package. It was noticed that the information and requirements for the planning level are specific to the procurement package.

The interviewees expressed commonly that plans should include at least some kind of quantities, dimensions, materials, masses, and structural types must be specified. Finally, it was raised again that the procurement should be able to list what plans and what level of planning are needed, and procurement format must be determined. Table 20 compiles discoveries and statements considering analysis about plans required by the procurement to be able to make proper invitations for tenders.

Table 20. Plans required by the procurement to be able to make proper invitations for tenders

Discoveries	Statements
The level of planning required by the procurement strategy and format is required for each procurement package.	*(INTVW 20) "The level of planning required by the procurement strategy and format is required for each procurement package"* *(INTVW 11) "Procurement formats must be specified. The content of the rougher plans can be improved by various proposals, but quantities are needed at least at some level"* *(INTVW 9) "Plans based on procurement strategy and formats are needed. The procurement should write in the procurement package card the required plans and their level of planning"* *(INTVW 8) "We must define the level of plans with their procurement formats and require a defined level from the designers"*
The information and requirements for the planning level are specific to the procurement package.	*(INTVW 6) "It depends on the title to be procured and the selected procurement method as well as market situation. Our procurement and design management should go through these things together beforehand, considering the required level of planning and procurement formats. Design management must find out what kind of plans the procurement needs with each procurement title"*
Plans should include at least some kind of quantities, dimensions, materials, masses, and structural types must be specified.	*(INTVW 7) "Plans such that they have quantities. Not necessarily as accurately as you can because we can use unit prices for the contract. However, some kind of quantities are essential. Structural types must be specified because they have an effect on delivery times and prices. Also, telling about special products is necessary because the delivery time can be many weeks or months. Designers do not always understand which products are standard products and which are not"* *(INTVW 19) "Plans must not be too precise but not too rough. The boundary is sometimes blurred. Determining the level of planning often requires experience from a procurement person. Nevertheless, information about quantities, dimensions, materials, masses, etc. must be delivered for the procurement"*

The activities of design management and procurement in order to make fluent working supply chain process

Everyone of the interviewees answered that interaction and collaboration are needed in order to make the supply chain process fluent. To enable continuous communication, it was suggested that both parties would work in the same room. Close and active cooperation between design management and procurement including production would be necessary. It was also notified that critical procurements must be identified in time to make the process fluent. It is important to find common interests between design management and procurement, thus a common understanding of the issues is important and awareness of things. It was discovered that project strategy and procurement strategy are important issues and interaction between the parties as well as coordination of schedules, splitting the project and synchronization of packages. Collaboration between parties and coordination considering the design packages and procurement packages and schedules were identified necessary. It was also stated that reviews about the design packages should be held together with designers before supplying the plans for the procurement. Table 21 compiles discoveries and statements considering analysis about the activities of design management and procurement in order to make fluent working supply chain process.

Table 21. The activities of design management and procurement in order to make fluent working supply chain process

Discoveries	Statements
Interaction and collaboration are needed in order to make the supply chain process fluent.	*(INTVW 20) "Interaction is really important for the whole chain" and (INTVW 19) "good leadership and clear roles with responsibilities are needed"* *(INTVW 15) "Interaction and informal discussions are really important between design management and procurement"*
It is important to find common interests between design management and procurement.	*(INTVW 12) "First of all one needs to know what the parties are doing. What the procurement is aiming for and what design management is seeking. A common understanding of the issues is important and awareness of things"* *(INTVW 14) "Both parties must be willing to assist the other party's needs to promote the delivery of the entire project. I support the thought that the procurement defines procurement formats for procurement entities in time beforehand, so that the design management knows how we are going to procure and what level of planning should be provided for the procurement"*
Collaboration between parties and coordination considering the design and procurement packages and schedules were identified necessary.	*(INTVW 18) "A description of the process and interaction is needed, as well as coordination of the design and procurement packages and schedules is essential"* *(INTVW 4) "Collaboration is needed with design schedule and packages as well as procurement schedule and packages"*

Collaboration between design management and procurement regarding design schedule, design packages, procurement strategy and plan as well as procurement packages

All the interviewees already told in the previous theme that there definitely should be collaboration between design management and procurement. It would be absolute necessary to have a common understanding about things, ergo, what one is going to do and how one is going to act. The realism of the planned things should be stated and investigated together. It is important for both parties to have a common understanding of the contents of the packages. It was notified also that one must work together to get a design schedule to support the procurement schedule. Another statement was that at the beginning of the project, all parties should be involved in the planning of things and it was suggested that one must write down what plans are needed in the procurement package and what plans are needed throughout design packages.

Interviewees stated that design and procurement packages and schedules must be coordinated in collaboration, but the frames of schedules and packages must be created before they are coordination to guarantee the quality of the coordination work. It was brought out that it also must be understood that changes will come to the plans, and these affects to design schedule or procurement schedule, thus one must check their coordination again as the project progresses. Table 22 compiles discoveries and statements considering analysis about collaboration between design management and procurement regarding design schedule, design packages, procurement strategy and plan as well as procurement packages.

Table 22. Collaboration between design management and procurement regarding design schedule, design packages, procurement strategy and plan as well as procurement packages

Discoveries	Statements
There definitely should be collaboration between design management and procurement.	*(INTVW 1) "Yes definitely. Coordination and cross-sectional check of the content of procurement packages and design packages should be done. There should be a common understanding of what we are going to do and how we are going to act"* *(INTVW 2) "It would be absolute necessary to have a common understanding about things, and ability to communicate to designers what level of planning is needed at any given time. All should be based on the needs of production and procurement. It is necessary to map the contents of the procurement packages and the required plans and their levels"*
One must work together to get a design schedule to support the procurement schedule.	*(INTVW 8) "Design packages must be based on procurement packages and their formats. Interaction is important"*
Design and procurement packages and schedules must be coordinated in collaboration.	*(INTVW 18) "The frames of schedules and packages must be in order before they can be coordinated"* *(INTVW 19) "Workshop styles can be good for coordination of design packages and procurement packages. Both parties have planned their own things, and then packages and schedules are coordinated and cross-checked together. Changes to them are planned together and parties are working to promote the whole entity. It takes time and resources and needs discussion and the right place to do it. For example, not remotely, but face to face. There is also a need for follow up and process monitoring which means updating packages and their coordination in the meetings at required intervals"*

Utilizing building information modeling between design management and procurement

In general, it emerged mostly in the interviews that BIM coordinator should be utilized between design management and procurement, and there should be a reconciliation of views on how the building information model is to be utilized and what levels of development are desired for building components. All the planning should be BIM and data-driven as well as quantities from the model should be utilized in procurement. It emerged too that employees would need more guidance and support relating to BIM aspects because the skill level was told to be really incomplete yet. Housing segment already has its own levels of development in BIM, however, there is also a need for the Business Premises segment to have some standard levels of development which can be determined project-specific later. It is necessary to raise the skill level of personnel. Obtaining quantities with reliable accuracy from the BIM was mentioned several times also as manual calculation of quantities takes a lot of time and illustrating contract boundaries with BIM in negotiations was expressed to be beneficial. Nevertheless, it was reminded that it must be taken into account that not all suppliers can use the model at all.

It was told that the goal is that building information modeling would happen with different levels of development in different phases of design work. The master plan design or draft planning phase should have coarser levels of development and they should become more accurate in the detailed design phase. Some of the interviewees expressed that there would be a need for proper standardization in the construction industry for the levels of development in building information modeling. Finally, it was suggested that BIM should be utilized so that in the final settlement of subcontract after the work has been done, one can compare

what quantities have been in the beginning when the subcontract was awarded and what are the final actual quantities, thus the extra costs cannot be charged. Table 23 compiles discoveries and statements considering analysis about utilizing building information modeling between design management and procurement.

Table 23. Utilizing building information modeling between design management and procurement

Discoveries	Statements
BIM coordinator should be utilized between design management and procurement. **There should be a reconciliation of views on how the building information model is to be utilized and what levels of development are desired for building components.**	*(INTVW 1) "BIM coordinator should be utilized between design management and procurement. There should be a reconciliation of views on how the building information model is to be utilized and what levels of development are desired for building components. We should get subcontracts more accurate when quantities could be obtained from the model"* *(INTVW 2) "All the planning should be BIM and data-driven, and procurement should be based on the data content of the building information model. Quantities from the model should be utilized in procurement"*
Employees would need more guidance and support relating to BIM aspects.	*(INTVW 8) "There would definitely be a need for guidance on how to use the building information model in projects and how to determine levels of development for building components and how it effects on the modeling work of building information model. It does cause more work and learning for the personnel, but it would be necessary. The BIM coordinator should monitor the implementation of the determined levels of development by building components, thus the procurement could utilize reliable quantities"* *(INTVW 9) "Nowadays, many building information models are just illustrative angles that can be viewed, but the other benefits of modeling and information content are not sufficiently exploited. There is a need for more instructions on how to use the programs, and how and where the building information model can be utilized, as well as how levels of development of building components affect the content of the model"*
Building information modeling should happen with different levels of development in different phases of design work.	*(INTVW10) "The goal is that building information modeling would happen with different levels of development in different phases of design work. For example, like they are using LODs in some other countries. We hope that general guidance on this subject will be provided in Finland in the future also"* *(INTVW 16) "At the beginning of the design phase, one must have coarser levels of development and later they can be at more accurate level. For HVAC and electrical engineering, the levels of development do not go the same way, and it depends on the design agency that what programs are used in the modeling work. The level of development can be definitive from the beginning of the modeling. The biggest help with building information model is to coordinate HVAC and electrical engineering as well as other fields of design with collision views"*
BIM should be utilized so that in the final settlement of subcontract after the work has been done, one can compare what quantities have been in the beginning when the subcontract was awarded and what	(INTVW 20) "Structure types must be specified as their own titles for quantities in the building information model. For example, VS4 a, b, and c by different dividing wall type prices so that quantities can be utilized correctly and reliable in the procurement. In the final settlement of subcontract after the work has been done, we can find out what quantities have been in the beginning when the subcontract was awarded and what are the final actual quantities, thus the extra costs cannot be charged from us. Consequently, the procurement should also tell design management what kind of units need quantities. No one has properly told in the company's BIM trainings what to do and how to do it. The focus has been mainly on software training. One would have to be aware of

are the final actual quantities.	the whole picture of the entire chain, for example, how the information created at this point is utilized later in production. Making the entire chain more efficient is based on that the parties also understand the activities of each other. Nevertheless, internal BIM coordinators would be needed to support the design management in projects"

Summary about development propositions

Based on the interviews it was discovered that the process should be described between design management and procurement, and the use of design packages and procurement packages would be the right process to start developing activities. The coordination work process of these packages is essential. A common understanding about the content of design and procurement packages is necessary, thus collaboration is needed. The procurement strategy for packages must be created and procurement formats must be defined for identified critical procurements. The design schedule must be tied to the money in design contracts and the expertise of project manager is emphasized. Reviews or inspections about the plans have to be held before the plans are supplied for the procurement because the level of plans must be verified in advance. It was suggested that standardizing design packages and some critical and repetitive procurement packages would help the entity so that operations would be less complex to control.

It was suggested that the level of planning required by the procurement strategy and format is required for each procurement package, thus procurement formats must be defined. The procurement strategy and format determine what kind of plans procurement needs to be able to make proper invitations for tenders, thus it is all about interaction and common understanding about how to procure each procurement entity between design management and procurement. Sometimes the design management wants to seek alternative solutions with normative plans from the subcontractor via the procurement and sometimes some entity is procured as production subassembly as well as other option is to purchase some package directly with detailed design level plans. Nevertheless, the plans should at least include some kind of quantities, specified structural types, materials, dimensions and masses. These things can have a huge impact on delivery times when procuring. Supplier and production capacity must be able to be reserved. It was suggested that the procurement should list what plans are needed in the procurement packages for the design management.

Collaboration and interaction are needed in order to make the supply chain process fluent. Communication should be continuous, and it would be good that both parties would work in the same room. Common interests must be found between design management and procurement, and active collaboration is required with design schedule and packages as well as procurement schedule and packages. Coordination and cross-sectional check of the content of procurement packages and design packages must be done in collaboration. Procurement strategy is important to create because it has an impact on every procurement package and that on design packages. A common understanding of the issues is essential and awareness of things. It was suggested that frames of schedules and packages must be in order before they can be coordinated, meaning that both parties plan their own things and then packages and schedules are coordinated and synchronized together.

It was instructed that all the planning should be BIM and data-driven and procurement should be based on the data content of the building information model. Reliable quantities

are needed for the procurement from the model and it depends on the levels of development by building components in the model. BIM coordinator should monitor the implementation of the determined levels of development by building components, thus the procurement could utilize reliable quantities. Contract boundaries could be also illustrated with the building information model in negotiations. Trainings and guidance are needed how to use the building information model in projects and how to determine levels of development for building components and how it effects on the modeling work and the content of building information model. The goal is that building information modeling would happen with different levels of development in different phases of design work. The master plan phase should have coarser levels of development and they should become more accurate in the detailed design phase. Standardization for the levels of development in building information modeling in the construction industry is desired. It would help also all the design companies to do their modeling work.

3.4 Synthesis of the main findings

Based on the interviews the topic of this master's thesis has been a challenge and a problem in the construction industry in general for years. Some of the interviewees had previously worked for other construction companies and shared their thoughts from that time too. The problem has been discussed in construction companies for years. Nevertheless, solutions have not been properly found or utilized in everyday activities. The literature framework serves as a basis for developing a solution and connecting things, and for understanding the overall picture.

According to the data search, some guidance can be found on the subject from the company's current new management system database and older databases. However, guidance is scattered into different locations and is somewhat unclear. Because the information is distributed into different places, it is difficult to find. Thus, the instructions cannot be followed correctly either. Nevertheless, the foundations for good data management exists as long as data discovery is developed, and data is centralized only into company's new management system database. The design management and procurement have their own guidelines for the processes but the guidance considering their relationship and interfaces doesn't exist properly. It is instructed that the design schedule must be created for the project and design packages as well as procurement packages must be determined and created. However, design packages and procurement packages are currently separate entities in the instructions and their connection is not expressed. Collaboration between design management, procurement and production is brought out in some instructions but the ways to collaborate is not provided or explained. Currently, the guidance in the management system database is provided at very general level and more specific guidance is needed, especially in the interfaces of design management and procurement.

As a conclusion, the target company doesn't have currently common processes between design management and procurement among different projects when prime contractor is responsible for design management. Design management and procurement function separately from each other and there is a need for common policies and process description. The answers from interview question 1 (company's present practices) supported this issue as it was directly reported that different methods are currently in use and common process description is needed. The interviews revealed that process descriptions are still underway and there are

no common practices yet. Currently, project managers have their own established manners or even rather poor manners considering the process. Without common policies, it is difficult to develop anything at all when there is no comparable data. Some projects are going well, and some are worse. There would be a need for some common process description and approach that could be developed further. Thus, creating always a new way of working on the project at the beginning of the project is not anymore needed as there would be common process. Sure, there are variables and projects are different, but there are anyway some similarities. The interviews brought out that a bold alignment from upper management would be needed to start promoting certain kind of policy with this issue between design management and procurement. Meaning that it must be chosen whether to use both design packages and procurement packages together or not in the supply chain process.

The design management and procurement don't have a common understanding about what plans and what level of designing is needed for each procurement entity. This refers to interview question 3 (company's present practices) as creating a procurement strategy and determining procurement formats is generally at weaker level. A common understanding of the strategy for each procurement package should be found in collaboration or otherwise designers supply the procurement with incomplete or wrong kind of plans, or they are delivered late. It was suggested that procurement should also list what plans and documents are needed for the procurement package and what level of planning is required to help design management's and designers' work. However, synchronizing design packages and procurement packages in collaboration would be essential and they are not synchronized at the moment properly. They have been treated generally as separate entities and there is a need for coordination work which can be complex. One big problem is that design work cannot be managed on a procurement basis properly. The design work requires a different implementation order than procurement and construction site's tasks because some things have to be planned as a whole and some things have to be planned already earlier to be able to plan a certain things. Therefore, design packages and procurement packages must be coordinated in order to make both sensible from their content and allow proper timing of all actions and supplying of plans. One difficult aspect to this issue is also that the owner's decision making must be bound to the design schedule somehow. Due to this, design packages and procurement packages must be taken into use and utilized together by coordination.

Based on the interviews, the use of design packages and procurement packages would be the right process to start developing activities and collaboration with good interaction is required between design management and procurement. The answers from the interview question 1 (development propositions) supported this issue as the importance of design packages and procurement packages was recognized considering the question about what is the process by which design management can produce plans for procurement at right time. A common understanding about the content of design packages and procurement packages as well as their coordination work process is essential. The procurement strategy for packages must be created and that way procurement formats determined for identified critical procurements. Based on the interviews, it was recommended that standardizing design packages and some critical and repetitive procurement packages would help the entity so that operations would be less complex to control. Nevertheless, the standardizing work of these packages is limited outside of this Master's thesis scope. Considering the BIM aspects, it was stated that all the planning should be BIM and data-driven as well as procurement should be based on the data content of the BIM. This could be achieved by standardizing LODs for building components

and BIM coordinator would monitor the implementation of the LODs in the model and support design management. However, currently standardized levels of development for BIM building components are being yet developed for the target company's Business Premises segment and design work is still only slightly managed by BIM.

The Table 24 summarizes the main points about challenges and development targets considering the supply chain between design management and procurement.

Table 24. The main points about challenges and development targets

• A common process between design management and procurement must be described
• The use of design packages and procurement packages is the right process to start developing activities
• A common understanding between design management and procurement is needed about what kind of plans and what level of planning is needed for each procurement package
• The coordination work of design packages and procurement packages is essential and must be described
• Collaboration with good interaction between design management and procurement is necessary
• All the planning should be BIM and data-driven as well as procurement should be based on the data content of BIM

4 Proposition for improving the supply chain process

In this chapter, the developed proposition for improving the supply chain process between design management and procurement is presented and described. The process between design management and procurement is first illustrated and later the improved operating model between the design packages and the procurement packages is presented. The theoretical framework developed based on the literature review acts as a support and background information for the proposition. The proposition is constructed based on the literature review, research about present state of the target company's practices and development targets as well as meetings about the subject in the target company.

There are many ways to practice things related to the subject and one right solution does not exist for this problem in question. However, it is necessary to choose a direction in which the development will be taken in order to harmonize the work between the projects and thus evaluate and develop things forward. The use of design packages and procurement packages was chosen to be developed based on the research, and target company's general desire. The design management and the procurement serve the needs of the production in the supply chain, which is why it is important to create the conditions for production to succeed. It is important that the design management can supply the procurement with complete right level plans at right time in the chain produced by the external designers, thus collaboration including good interaction between design management and procurement is required.

4.1 Process description about the supply chain between design management and procurement

The whole process requires proper resource allocation in the very early phase of the project, and time for project planning must be reserved before starting the project and detailed design work. Project manager, procurement engineer and construction manager are required in the planning of the project, even though if individuals are not final in the project, the project directions including design schedule and packages, procurement strategy and formats as well as procurement schedule and packages, and also general schedule must still be planned.

In general, the starting points for master plan design and detailed design phases are that master plan design phase must be implemented with starter design packages utilizing "Push" principle. This means that design management produces the main drawings in accordance with the objectives planned for the building based on the objectives of the owner, whereas detailed design phase must be implemented with design packages and procurement packages including procurement formats utilizing "Pull" principle. This in turn means that in project planning phase general schedule is created by construction manager, and based on that procurement schedule and plan including procurement packages and formats is created by procurement engineer as well as design schedule for detailed design phase including design packages is created by project manager. Starter design packages contain all the initial design data required for the detailed design phase design work. They must produce master drawings (space concepts, model room, building specification, floor plans and sections etc.) in the master plan design phase. Figure 22 illustrates the difference between master plan design phase and detailed design phase considering the design management point of view and their content.

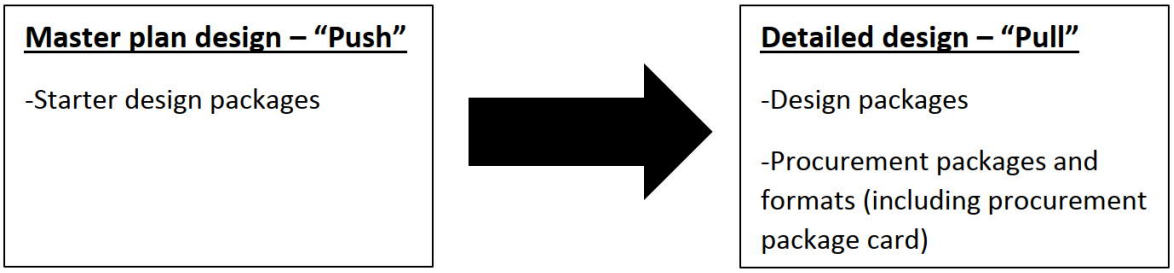

Figure 22. The difference of contents between master plan design and detailed design phases

Considering the BIM aspects, the LODs must be definitely determined for the building components and for the project in question early, or standardized LODs must be used if available. LODs must be tied to design contracts by project managers because otherwise designers will not follow them. BIM LODs must be determined for a rougher level for the master plan design phase so that drafts are not modeled too accurately. This saves time and unnecessary work as plans often change a lot at the drafting stage and even afterwards. For the detailed design phase, more accurate LODs must be defined. BIM coordinator must support the design management and take care of these aspects together with the design management. The entire design management must be a BIM and data-driven, involving the BIM coordinator to support the design management and verify that the LODs are implemented as agreed in the design. Otherwise, the quantities obtained from the BIM, cannot be relied on by the procurement. It would be important that the procurement could utilize reliable quantities from the BIM in contracts, and afterwards when subcontract's tasks are completed at construction site, it could be checked from the updated BIM in the final settlement of subcontract how the quantities have changed in the BIM. This would prevent fraud in terms of additional invoicing when the quantities would be comparable to the quantities at the time of awarding the subcontract. Nevertheless, the determination of LODs gives the right kind of quantities for the procurement with the right units for subcontracts, ergo, the quantities of the BIM would be presented in the same units and formats as the procurement must use in the subcontracts. How far one wants to take LOD accuracy in any building component depends only on the company and the project's own needs. Procurement format also plays an important role in this matter, how precisely and to what extent things are planned in the BIM. Even if an entity is procured as a production subassembly, the subcontractor's building information modeling must be specified with defining LODs for the contract if the model is to be used properly for example during the building's lifecycle. However, new common LODs would be needed for the construction industry in Finland, which could be relied on in the design agreements. If prime contractors always set their own LODs, the designers get confused, and new design settings for each project create an almost unreasonable challenge and difficulty for the modeling work.

A process flowchart between the design management and the procurement was developed and constructed for the artefact proposition to solve the problem in question (Figure 23). The process starts with proper resource allocation for the project planning and with determination of LODs for BIM. After this, construction manager creates a general schedule for the construction project and schedules the site tasks so that they can be completed as planned. The whole supply chain is based on the need to create the conditions for the construction site to succeed and the phases of the chain are all that way based on the created general schedule.

Thus, next phase in the process is that the procurement plan and schedule are drawn up on that basis. The procurement strategy is essential to create for the project and procurement packages. Therefore, the procurements must be determined and distributed into different procurement packages. Defining procurement formats and the needed level of planning, at least for critical procurement packages, is essential in the process. Rougher plans can be used to query different solution options and get potential savings from them, as well as to reserve supplier capacity with some kind of quantity data, even if the plans are not of the detailed design level. Procurement performed with detailed plans (one of the procurement formats) is not always needed with each procurement package, thus the mere role of the buyer is irrelevant considering the procurement. Due to this, different procurement formats must be selected for each package and that way the required level of planning determined. This requires collaboration between the procurement and design management to achieve a common understanding about the strategy with each procurement package, and this has a direct effect on coordination work of design and procurement packages. Defining procurement formats also opens up a discussion between the design management and the procurement so that the project manager can point out which issues and packages would require alternative solutions. Thus, in that case procurement format can be, for example, procurement performed with normative designs. As a result, preliminary procurement packages (at least critical packages) are formed with defined procurement formats and after that procurement plan and schedule are created. A procurement package card should be created for every package in order to support the coordination work of design and procurement packages as well as the design management's and designers' work. The procurement package card can express the required plans and their level of planning regarding the procurement package in question. The procurement package card should contain the name of the procurement package and procurement format, the content of the procurement package including contract boundaries, the schedule of the procurement package, the required plans and initial data from designers as well as the needed time for the plans considering the procurement. Standardizing procurement package cards from recurring procurement packages would ease the workload when the card could only be updated for each project. Nevertheless, standardizing these procurement packages cards is limited outside of the scope of this Master's thesis. Appendix 3 shows an example of procurement package card template.

The initial design schedule is created on the basis of the general schedule and the procurement plan and schedule. A standardized design package division can be used in the process if one exists in the company or the design packages can be formed for the project. What is important about design packages is their timing and content. The design package produces plans for multiple procurement packages and thus includes design entities that have dependencies in the design process, what things need to be already decided and designed in order to be able to design the plans required by the procurement packages allocated to the design package in question. As a result of the completed design package, the agreed plans are delivered at the time agreed for the procurement. Due to this, the coordination work of design and procurement packages is essential in the process and it must be implemented in collaboration between design management and procurement based on the frames of general schedule. The coordination work is complex and has many dimension and dependencies, thus subchapter (4.2) covers the process related to it. It must be also stated that rewarding the designers should be tied to design packages so that designers have a goal to complete the design package on time and with the right content. Lastly, based on the coordination work of design and procurement packages, adjustments are created to the design schedule.

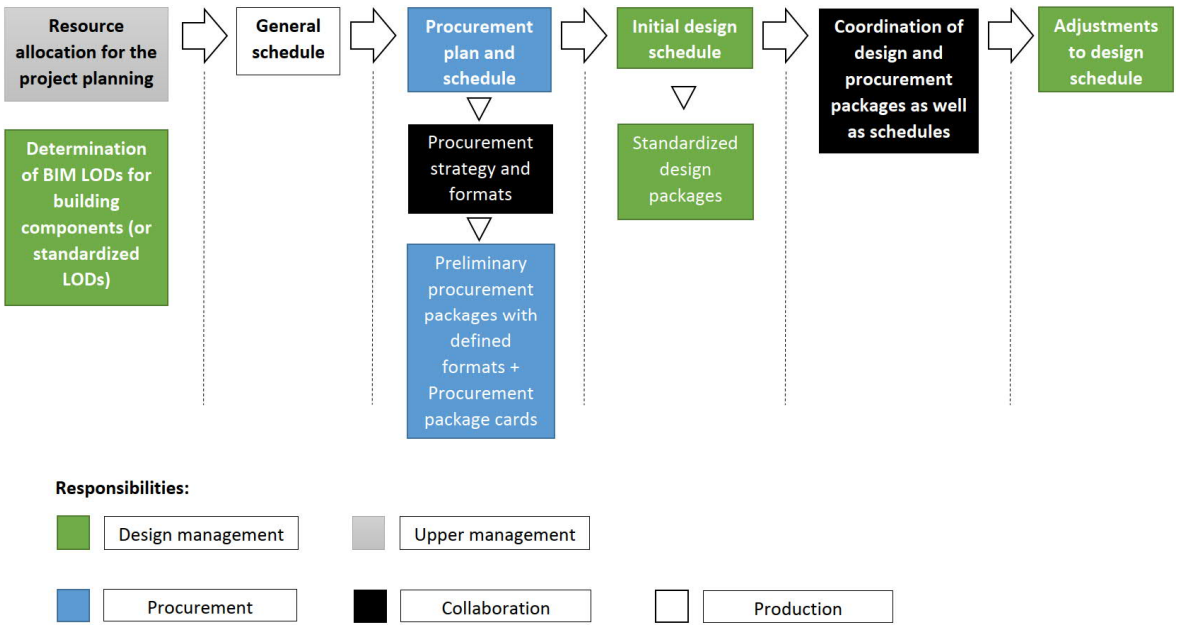

Figure 23. A process flowchart between design management and procurement in the detailed design phase

After adjustments, the design work and the first design package from the detailed design phase are started. Therefore, the process proceeds to the design package delivery process shown in the Figure 24. The design package delivery process involves mainly the design management, the designers from different fields of design and the BIM coordinator but the procurement also participates in inspections about the design package and sometimes point of view of the production is needed too. However, process starts with advance inspection about the design package. The procurement packages and formats, as well as both the required plans and their level of planning from the procurement package cards, related to the design package are reviewed in a collaboration with the design management and the procurement. Thus, based on the advance inspection, necessary changes and replenishments are created to the content of the design package. Advance inspections about the design packages should be held well in advance of its start in order to have time to make necessary changes and replenishments to their content. The next phase in the process is that design package is started and instructed to the designers. It is important that the design management holds a start meeting where the content of the package is instructed to the designers so that they understand what things and what kind of things need to be planned and what is the level of planning, and given time as well as priorities considering the package. After this, the process proceeds to the design work phase which includes cyclic design meetings where also BIM aspects are considered. The inspection about the design package will be held at the agreed time according to design schedule before designers supply their plans for the procurement. Compliance with the technical and financial requirements and the necessary plans and their level of planning will be assessed, and also building information model will be checked. If deficiencies are found, they are recorded by the design management and later corrected by the designers. The inspection should involve at least the design management, the BIM coordinator, the procurement and the designers. Finally, in the end of the process, the design package is approved, and plans are supplied to the procurement. In the same way, all design packages go through the process and supply chain to the end until there are no more design needs and deliverables for the procurement.

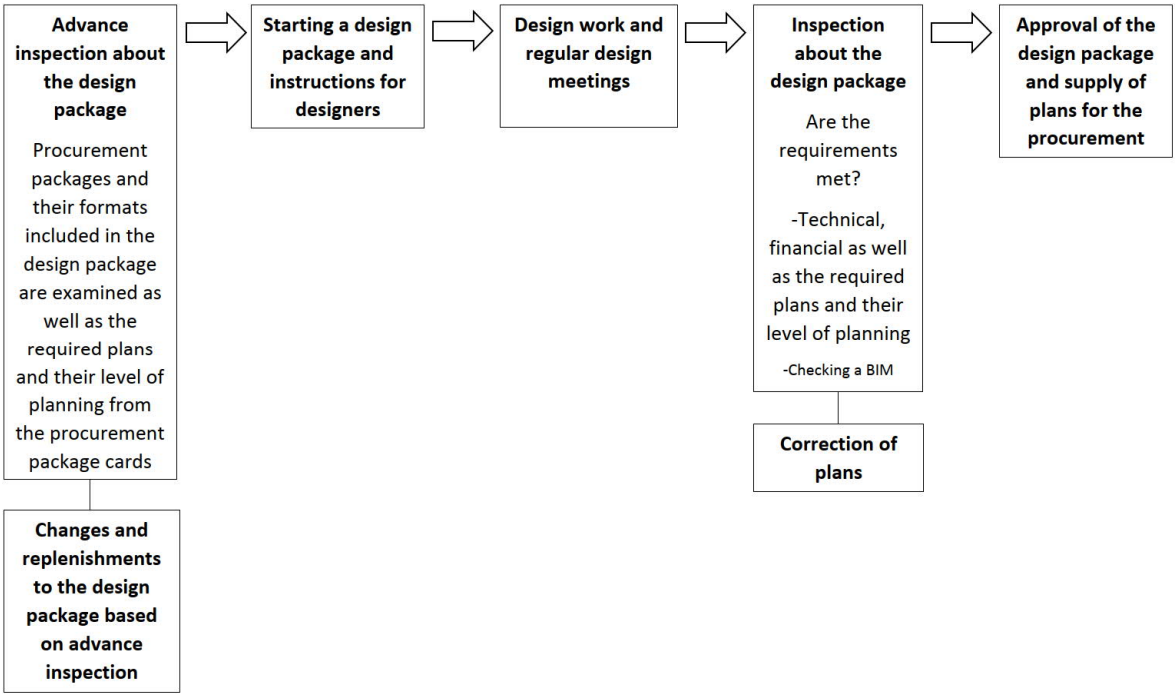

Figure 24. A process flowchart for the delivery of the design package

4.2 Improved operating model between design packages and procurement packages

In project planning phase, when preliminary design packages and procurement packages with their schedules are formed, the packages must be coordinated based on the general schedule. Otherwise, the design management cannot produce plans that serve the procurement at right time with required level of planning. It is important that preliminary design packages and procurement packages are formed before the coordination work because that way the design management and the procurement familiarize themselves into the project and its properties properly. This enables both the design management and the procurement to identify problems and inconsistencies during the coordination work. This leads to the fact that the coordination work of design and procurement packages requires project manager, procurement engineer and possibly construction manager being involved in it. A common understanding and agreement about things are the desired results from the coordination work, as well as coordinated packages when inconsistencies have been removed between them.

In the coordination work, it is examined and determined whether the design and procurement packages are synchronized and whether there is a common understanding of issues between the design management and the procurement. The aim is to identify the dependencies of things and their effect on the order of design and which design packages produce plans for which procurement packages and at what time. The dependencies consist of owner's decision making, design solutions and choices, order of production, order of procurements, need times for plans, procurement strategy as well as formats, things that need to be designed already earlier to be able to design and produce plans and documents that are required to be produced from certain design packages. The packages will be coordinated, and their feasibility will be assessed in a collaboration. It is influenced by the procurement format that

which design package produces plans for the procurement in question and at what time, as for example, with production subassembly format (procurement performed with design requirements), subcontractor must be involved earlier in the design process due to their design responsibilities, compared to procurement package which would be executed with detailed design provided by project's designers. Nevertheless, other influencing factors are the need times for plans, company's annual agreements and delivery times of products or subcontracts. It is important that the procurement strategy is created for each critical procurement package in a collaboration between the design management and the procurement in time before the coordination work because a common vision about procurement formats is indispensable. One must decide what procurement packages are performed as production subassembly and what packages need alternative solution options and what are performed directly with detailed designs. All these affect the level of planning required from a procurement perspective. Thus, with procurement formats one can communicate to designers what level of planning is required for each procurement package in the certain design package.

The design packages are depended on the decision making of the owner, thus this must be also taken into account in the coordination work and the final moments of the decision making must be planned for the owner. Otherwise, the entire project will be delayed and the whole coordination process will have to be redesigned due to dependencies. This issue emphasizes project manager's experience and expertise in identifying the decisions that need to be made for the design work.

A coordination Excel-tool, for coordination work process of the design and procurement packages, was developed and constructed for the proposition to solve the problem in question. Appendix 4 presents the coordination tool. The view in the coordination tool is divided into owner's decision making, coordination of design and procurement packages in detailed design phase, things that need to be planned earlier as well as plans and documents to be produced. All these parts have effect on each other, thus dependencies must be discovered and inconsistencies deleted. Owner's decision-making -part involves all critical decisions that have effect on design work progressing and continuity which must be decided by owner and deadline times for them. Project manager has to identify the necessary things which must be decided to allow continuity in the design work and prevent subsequent additional costs due to changes. Project manager's experience and skills are emphasized in this area because it can be challenging to identify only the essential decisions and ignore other irrelevant aspects here.

The coordination of design and procurement packages in detailed design phase -part includes determined design packages for the project or company's standard design packages or SUKE-model standard design packages. Starter design package contains all the initial data from the master plan design phase and acts as a basis for the first design package in detailed design phase and owner's decision. All design packages produce plans for certain procurement packages, thus different procurement packages are allocated to them, and procurement format and procurement package card are involved in every procurement package. All preliminary critical procurement packages must be distributed and allocated correctly for different design packages depending on their need times of plans, procurement formats, company's annual agreements and delivery times of subcontracts or materials. A preliminary critical procurement package refers to a procurement package that is identified and affects the schedule and delay of the entire project in the event of failure. It can also mean a cost-

critical and significant procurement from a procurement perspective. Nevertheless, procurement package card must be created or fulfilled by the procurement engineer for each procurement package to inform the design management what are the required plans and their level of planning (defined procurement formats) considering certain procurement package and that way support design management to form design entities for certain design package. Thus, plans and documents to be produced -part must be fulfilled based on these required plans. However, after these are fulfilled, one must consider also things that need to be planned earlier -part to connect what things must be planned and designed earlier to produce the required plans for this design package. It is important that the tool can be used to illustrate the dependencies between decision-making, design packages and procurement packages, plans to be produced and things that need to be planned already earlier.

It is essential that the design management is able to communicate to designers what plans and what level of planning is required for different procurements through procurement formats and procurement package cards. Otherwise, the process will not work according to the principal purpose and will not help the problem in question. However, the coordination process of these packages should help and facilitate the design management to form sensible design entities and guide designing to needs of the procurement and thus also to needs of the production. With help of the coordination tool, one can compile the required plan content into design packages with the help of procurement package cards and to determine the location of procurement packages between the design packages. The owner decision-making time can be also combined with the entity, ergo, when something must be decided to ensure continuity of design work, procurement and production. With help of determining design packages, the boundary for the design of a fixed support part and transforming infill part can be determined for the project. Once the coordination process is done, the project can continue to the delivery process of first design package. It must be stated that the coordination work should be done always again during the project if any big changes will occur that have effect on the schedule or packages.

4.3 Validation and evaluation of the proposition

Validation and evaluation of the proposition for improving the supply chain process presented was carried out to involve critical thinking into analysis about created proposition. Free-form interviews were held in a form of meetings to assess potential functionality orally and comment on the content of the proposition. Professional individuals were selected for validation interviews and they consisted of a head of developer contracting, a procurement manager and a procurement engineer.

The process description proposed seemed to be a good and right model that could unify operations between design management and procurement. The correct relevant parts were found in the description and the process is described in the right way and in the right order. It was good that the process has been described at general enough level to serve as a basis for different projects which however include project-specific variables and different characteristics that must then be applied to the procedure. With such a process in question, one should start to unify operations between design management and procurement and begin to drive it for use in the company. The proposal serves as an iron wire or, in fact, a rail for the run-in of interplay culture between the procurement and design management. Resource al-

location is very important for the project planning because there is a need to engage individuals to plan for these issues in a timely manner and to form a unified view that is changed only for well-founded reasons. The coordination tool seemed to be a competent scheme of things and a tool to start planning contexts for design and procurement packages as well as to open discussion and generate a common understanding between design management, procurement and production. Connecting the owner's decision-making is an important part which emphasizes the project manager's expertise and experience in identifying the right things that need to be decided in order to be able to design and later construct on site. The author has identified the right elements characteristics and challenges related to this issue and managed to illustrate well the issues in the proposed solution, which will certainly provoke more discussion and has been a good development work on the issue. The author has a good understanding of the challenges and interdependencies on which the proposed solution is based. The challenge is to implement the operating model, but it is only necessary to decide that, for example, the procurement strategy for packages must be made before moving forward in the process, and this proposed approach must be used in future operations and individuals cannot act differently on the basis of their own opinion. This topic of the thesis in question has been a common problem in the construction industry for a long time, but this proposals for a solution is a good step forward and can be used to develop things also in the future.

The coordination tool (Appendix 4) and procurement package card template (Appendix 3) presented could be developed in the future and incorporated into the company's procurement plan tool. Loose tables and tools often do not stay up to date with each other, thus it would be a good idea to put them together in the same tool. However, the proposition seems to involve good ideas and can be used as a basis for building future action.

5 Discussion

As a result of this thesis, a solution proposition for improving the supply chain process between design management and procurement was developed based on the literature review and research implemented in the form of mapping the company's current state and interviews. Design management and procurement have been both studied earlier, but their deeper connection in the supply chain process has been paid less attention. Especially, the prime contractor's procurement perspective and connection to design management have been lacking research. Nevertheless, this thesis takes a stand on this issue. The literature review supported well in finding a solution proposition to the problem in question and structuring the author's thoughts, as well as forming an understanding of the key issues related to the work. Based on the literature review, a theoretical framework was created between design management and procurement in the construction company's internal supply chain, which serves as background information for the solution proposition.

There is no one right solution to the problem and process under consideration, and things can be practiced in many ways. However, a coherent common approach needs to be established in the company in order to develop operations in general and to study the success and suitability of processes. Based on thesis research, it was decided to develop the use of design and procurement packages in the supply chain in order to serve the procurement better with produced plans at right time with correct content and level of planning. The proposed solution builds on the literature and previous research on the subject, but the proposed solution introduces a new perspective on the connection of the procurement strategy including procurement formats to the design needs and required level of planning as well as management of the internal supply chain as a whole. The improved supply chain process proposition fits well with the current goal of aligning the supply chain process between design management and procurement.

The coordination of design and procurement packages through procurement strategy and formats (the link between design management and procurement) has proven to be a new thing and solution, which neither Kruus & al. (2006) SUKE-model has presented nor was found in the literature. The problem with the use of design packages alone or the SUKE-model is precisely that the procurement distribution is made too freely concerning the design packages which produce plans for different procurements. The procurement strategy and formats are not properly taken into account concerning the forming of design packages, thus coordination work is missing. Which leads to the fact that procurement still gets the wrong level of plans and usually late, when critical decisions are made too late between the owner and the design management from a procurement and production perspective. The challenge is also to identify critical decisions for the coordination process on behalf of the design management to the owner, which are based on the needs of the procurement and the production in the chain concerning plans. The process of coordinating design and procurement packages adds novelty to the thesis, as the interviews also revealed that design and procurement packages have generally been kept too separate entities in the construction industry and their coordination has not been understood to implement through procurement strategy and formats.

Another novel thing is BIM aspect, as in general, the level of building information models is still weak in Finland, and the determination of LODs is a fairly new thing in design man-

agement. This was manifested in the fact that based on interviews even some of those responsible for design management did not understand what things and how can be influenced by the LODs in BIM. Thus, in this supply chain process between design management and procurement, proper determination of LODs adds value to the right content of plans and the level of planning. Uusitalo & al. (2019) described applying LODs for project's building components, but this thesis went more deeper into strategic process itself and emphasized the significance and influence of procurement strategy and formats into determination of the required LODs for building components.

The third novel thing is the thesis' focus on the interface between design management and procurement. In general, existing research on the subject nearly always focuses strongly on either design management activities or procurement activities, thus the description and consideration of the actions between the parties has remained slight, which continues to create problems in the industry in this chain. For example, Bølviken & al. (2010) article described developing collaborative design management on such projects where design is partly carried out in parallel with construction, but the deeper connection between design management and procurement was not brought out as the article concentrated on design management aspects. For another example, Koniel (2019) Master's Thesis concentrated strongly on developing design management activities to eliminate detailed design waste, but interface and activities between design management and procurement was not considered. The developed process description about the supply chain between design management and procurement in this thesis improves performed actions and the smoothness as well as comprehensibility of the process.

However, cooperation between the parties, interaction and the sharing of information are essential. A unified view of things must be formed between design management and procurement during the project planning in order to create conditions for subsequent activities to succeed. Transparency of information is also important to designers to a certain extent considering why plans are needed at required time for procurements and which procurements are number one priorities and where there is room for flexibility. Thus, proper instructing of designers considering the design package, and their management is an important part of the supply chain process.

The use of the proposed solution requires a broad understanding of the whole supply chain, and the coordination of things as well as determining and deciding is very complex, although this solution facilitated the management of the whole by breaking things up into suitably sized packages with dependencies. There may be a feeling that everything affects everything because of dependencies and not all the necessary information is always available when design and procurement packages are created and coordinated. But by making decisions, for example, on the strategies of procurement packages, it is possible to move forward in the process. Decisions must be taken, and things must be applied together, and the direction must be chosen even if the background information would be incomplete at the project planning stage. Project-like activities and uncertainty forces one to make choices and compromises about things based on the best estimation about issues. The proposed solution has been prepared at general level so that it would be also suitable for use in different projects and within different project forms and project characteristics. Proposed solution provides guidelines and principles for practices, but it does not replace the need for professional expertise or ability to apply on a project-by-project basis due to the complex business world of business premises construction.

The implementation of the solution proposition and the thought model can be challenging due to the culture of resistance to change, and people would have to learn new things and start thinking about doing things differently. Interplay culture should be driven in and got rid of stubborn practices and silo effect. In the future, the proposition should be tested in the company's operations between design management and procurement, in order to gain an understanding of its functionality and new development ideas for the process. Nevertheless, the proposed solution should be incorporated into the company's management system's guidelines, and small-scale training may be required for the implementation of the proposed solution.

As the solution proposition is drafted at a general level and is not limited to the target company, it is generally suitable for use by any prime contractor in business premises projects where they are in charge of design management. Proposition is also suitable for projects where the owner requires the use of design packages as part of the project delivery. For example, it was discovered during the interviews that many owners have insisted the use of design packages in their projects, thus proposition could also be generalized to the activities of other companies in projects where the owner requires the use of design packages, and the prime contractor is in charge of design management.

The combined use of design packages and procurement packages should improve the systematic and more efficient implementation of the supply chain between design management, procurement and production. Thus, it should improve serving the needs of procurement through design. Nevertheless, future research should compare the combined use of design packages and procurement packages with other methods where design is managed by procurement basis or by design packages alone. One should somehow measure the timeliness of supply of plans and the correctness of content between these different methods.

5.1 Fulfillment of objectives and research questions

The objective of this thesis was to define effective and efficient supply chain process between design management and procurement when prime contractor is in charge of design management. Based on the literature review, a theoretical framework for the supply chain process in question was created. In the research part, a deeper operational process was developed with the help of research and a process description was created about the supply chain between design management and procurement. The process description involves a process flowchart between design management and procurement in detailed design phase and a process flowchart for the delivery of the design package. Both processes must be completed in order for design management to be able to supply plans for procurement at right time with right content and level of planning. The research questions could be answered as follows:

The first research question was worded as follows:

"What are the problems and challenges in the supply chain process between design management and procurement?"

Based on the literature review and research, it was discovered that when the design work had been managed on a pure procurement basis, it had led to problems in the supplying of

the plans. In studying the literature, the author came across Kruus & al. (2006) SUKE-model, which mentioned this problem in question. Design work cannot always be carried out in the same order as procurement and site tasks because sometimes things must be planned already further in order to be able to plan the things needed for procurement. In this case, the decision-making of the owner and the ability of design management to identify the necessary decisions that need to be made for the continuous design work come along. Nevertheless, the design must serve the needs of the procurement and the production, even if it cannot be managed on a procurement basis. For this reason, it is a good idea to use design packages for design work and procurement packages for procurements. However, their coordination needs to be performed although it can be challenging.

The key problem in the target company was that there was no common process existing between design management and procurement. Activities were performed differently between different projects based on the habits experienced by the individuals as good, thus a common process description was desired and needed. Another key problem was that there was no common understanding between design management and procurement about what plans and what level of planning is needed for each procurement package at what time. This was reflected from the fact that a proper procurement strategy and formats were not planned for procurement packages at the project planning stage of projects. The supply chain was not efficient and working as the supplied plans were drawn either too rough level or too detailed level or the plans were incomplete or late from the given deadlines. Design management and procurement must generate a common understanding about the content of design and procurement packages in order to be able to communicate to designers what plans and what level of planning is required and as well at what time certain plans are needed. Finally, it can be stated that the first research question could be answered on the basis of literature review and research part of this thesis.

The second research question was worded as follows:

"What kind of plans procurement needs from designers to be able to make proper invitations for tenders?"

It was discovered based on the literature review and interviews that the procurement does not need always detailed design level plans from designers for being able to make proper invitations for tenders. The purpose of the procurement is not just to purchase everything directly with detailed designs, thus procurement should also be able to look for alternative design solutions to the plans from the subcontractors in order to support design management and find more cost-effective solutions or achieve cost savings. Some alternative solution options can even be better from their functionality considering maintenance and lifecycle than original solution. This leads to the conclusion that the procurement needs plans in line with the procurement strategy and format which are determined for each procurement package to be able to make proper invitations for tenders. The design management and the procurement must collaborate and determine together procurement strategy and format for each critical procurement package in order to have a common view of things. It can be suggested that Kruus & al. (2006) SUKE-model's procurement formats (presented in the subchapter 2.5.3) could be used to determine and describe procurement formats, and that way define the required level of planning for plans for the designers.

During the research, it became clear that the plans should include at least some kind of quantities, dimensions, materials, masses, and structural types must be specified. The procurement should be able to express and list what plans and what level of planning are needed for each critical procurement package at rough level, thus procurement package card template (Appendix 3) could be used for this purpose. At the same time, it would help the design management to form the content of design packages and make them comprehensive. It can be stated that the second research question could be answered by combining the information together from research interviews and literature review.

The third research question was worded as follows including three sub-questions:

"What is the process by which design management can produce plans that serve procurement at right time?"

- *"What are the needs of both parties in order to make fluent working supply chain process?"*
- *"How should design management and procurement collaborate to achieve the state that design packages and procurement packages would be sensible and aligned?"*
- *"How Building Information Modeling can be utilized in the process between design management and procurement?"*

Based on the literature review and interviews, the use of design and procurement packages was chosen to be developed. The third research question was answered in the chapter 4 which describes the process by which design management can produce plans that serve procurement at right time with right content and level of planning. The process involves two different process flowcharts. First there is a process flowchart between design management and procurement in detailed design phase which consists of things that should be planned in project planning stage for the project itself. Proper resource allocation for the project planning is essential to implement the process and BIM LODs must be defined in the very early phase. Once the general schedule has been drawn up, the procurement plan and schedule as well as design schedule are mirrored from it. Procurement strategy and formats for critical procurement packages play an important role. Preliminary procurement packages must be determined, and standardized design packages can be used. It is very important to coordinate design and procurement packages in collaboration so that they are sensible and synchronized. Once packages are coordinated and schedules are made from them, the design work will begin and the delivery process of the first design package will begin. A separate process flowchart was created for this, because the delivery process of the design package is repeated as many times as there are design packages determined for the project and only the design package being processed changes. An advance inspection about the design package must be held to check and update the content of the package and after that the package must be started and instructed for designers carefully. Then the process proceeds to cyclic design time containing regular design meetings. Before approving the design package, an inspection about the completed design package must be held in order to verify that the requirements are met, and BIM is up to date. Eventually, the design package is approved, and plans are supplied for the procurement by designers.

Collaboration and good interaction between design management and procurement are essential. Especially, concerning the determining and creating procurement strategy and formats as well as the coordination work of design and procurement packages. A common vision must be formed of things in the project planning stage and the parties must understand each other's work. Work must be done for the common good and not for one's own benefit. Both parties must be willing to assist the other party's needs to promote the delivery of the entire project. The whole must be understood as a chain that serves procurement and thus production. It can be stated that a fluent working supply chain process requires activity as well as the flow of information and a common understanding of issues. However, it also requires decent project planning and a common process description between design management and procurement for one being able to implement things similarly among different projects. Following the defined processes is again a challenge in itself.

Based on the research, design management and procurement must coordinate the design and procurement packages in collaboration to achieve the state that these packages would be sensible and aligned. For the coordination work, a coordination tool for design and procurement packages in detailed design phase (Appendix 4) was developed, thus it could be used for this purpose. The dependencies of things must be discovered, and inconsistencies eliminated. The experience and professionalism of the individuals are emphasized in the coordination work. Nevertheless, subchapter (4.2) deals with these things deeper and answers to the sub-question related to collaboration between design management and procurement and achieving the state that packages are sensible and aligned.

Considering how BIM can be utilized in the process between design management and procurement, it was discovered on the basis of literature review and interviews that the usability of the whole BIM model depends on the determination of LODs for building components for the project. LODs must be determined for the building components in the very early phase of the project or standardized LODs must be used if available. BIM LODs must be defined for a rougher level for the master plan design phase and they must be more accurate in the detailed design phase. BIM coordinator must support design management in these aspects and verify that the LODs are implemented as agreed in the design. Building information modeling provides benefits for design work, design management and procurement. For example, coordination of design work is more effective and collision detection can be utilized. Subchapter (2.8) concentrates deeper on BIM practices and its utilization. However, building information modeling can be utilized for obtaining reliable quantities from the model for procurements and contract boundaries can be also illustrated with the model in negotiations. Thus, quantities can be used in awarding subcontracts and later after completing work of subcontract they can be checked from the updated model in the final settlement of subcontract. In studying the literature, it was discovered that building information modeling improves the quality of design work (Azhar, 2011), which in turn improves the quality of plans supplied for the procurement.

Finally, it can be stated that the third research question and three sub-questions could be answered based on the theoretical framework, literature review, research part of this thesis and developed solution proposition.

6 Conclusions

The Design Science Research method suited well for this thesis purposes as it provided knowledge through the systematic literature review, allowed connecting empirical research part to the developed theoretical framework and finally enabled the creation of an artifact which came out in a form of solution proposition for the problem in question. Through the method, a comprehensive understanding of the problem was achieved which enabled the examination of different contexts related to the issue. A satisfactory solution was obtained for the problem even it would not be optimal, thus the study clearly benefitted from the use of the Design Science Research method. The topic of this thesis is very complex and has been problematic issue for the business premises construction industry for a long time, thus the author's own systematic research plan developed on the basis of the method served very well as a basis and indicator of direction during the research, although the topic was difficult and there is no one right solution to the problem.

This thesis studied how the supply chain process between design management and procurement could be improved in projects where the prime contractor is responsible for design management and design work is implemented possibly concurrently with construction. The challenge is to supply plans for the procurement from the designers and design management at the right time and with the right content. The connection of design and procurement packages is emphasized in this matter and the basis for their coordination is established from the procurement strategy and formats of each procurement package. Determining procurement strategy and formats for procurement packages in the project planning stage must be implemented in collaboration between design management and procurement in order that the parties form a common view and understanding of the issues. How things will be procured and in what order what plans are needed and what level of planning is required. Thus, collaboration and good interaction between design management and procurement is essential for being able to improve the supply chain process.

As a result of this thesis, a proposition for improving the supply chain process between design management and procurement was developed and created. A theoretical framework for the supply chain process between design management and procurement was created based on the related features and aspects from literature review. Based on it and the empirical research part, a process description about the supply chain between design management and procurement was created. The description involves a process flowchart between design management and procurement in the detailed design phase and as well a process flowchart for the delivery of the design package. Also, a coordination tool for design and procurement packages was developed and presented to improve operations. As a whole, an improved supply chain process was achieved between design management and procurement. The described process enables the design management and the procurement to plan the relevant things in collaboration and to create a common understanding of the future activities of the project, through which the necessary plans for the procurement can be supplied at the right time with the right content and level of planning. However, there must be uniform processes between the projects in order to be able to develop things also in the future, for example, on the basis of this described process, and the whole must be seen as a chain that serves procurement with plans and thus production.

6.1 Limitations of the research and validity

While the Design Science Research method suited well for this thesis, and methodology as well as systematic literature review as a background were treated and discussed, there are however some limitations of the research conducted which must be brought out. There was not enough time to implement and test the proposed solution and it was therefore excluded already at the beginning of the research. Thus, this thesis does not provide any empirical evidence on whether how much the supply chain process is improved in practice and how challenging the solution proposition is to implement for use for the functions. It can be also stated that the role of validation for the proposition remained somewhat light even though professionals were interviewed about its content and workability. The practical validity could have been improved by testing the proposition in practice and validating it with more interviews.

Another point of view is the process validity of the developed solution proposition. Even though the process proposed was described well at general level and its development was conducted systematic by utilizing literature and qualitative interviews, the author conducted the research mainly independently, thus external evaluation and inspection considering the author working on research was not executed. On the other hand, communication and interaction with thesis advisor and company's professionals made the process development and research effective.

Finally, it should be mentioned that in this thesis one had to choose some kind of development direction based on the research and company's general will, thus this thesis is limited to examine only the combined use of design packages and procurement packages in the proposed solution, even though there are also other ways to practice things between design management and procurement.

When considering deeper validity and reliability, they can be defined often from two different perspectives. Whether the measurement or research method is valid and / or reliable as well as whether the conclusions drawn from the results are valid and / or reliable. (Hirsjärvi & al., 2009.) The Design Science Research method was valid as it suited extremely well for this problem in question providing suitable research structure for the thesis and had solution providing ability, for human purposes, thus solution proposition could be provided through the method. The reliability of the research method is influenced slightly by subjectivity as the author formed theoretical framework based on his own choices about theories utilized in the literature review, thus other person could have probably ended up with a little different kind of theoretical framework. Nevertheless, the research structure with qualitative interviews would have given in some way same results in the empirical part and same conclusions could have been drawn. The conclusions drawn from the results are valid as the validation and evaluation of the proposition was conducted with professionals and the research has been done thoroughly following the research method and plan as well as critical thinking. The conclusions are based on research implemented systematic, thus it supports the validity of the conclusions drawn. Conclusions drawn from the results are mainly reliable as similar conclusions could have been drawn by repeating the study again as it stands.

When considering reliability of the used data for the proposition, data searched and found from company's databases illustrated exactly what kind of guidance from the company's management system was found on the topic and what things were required to be done. The

data was just as reliable as the current instructions in the company were at the time. It was important to discover what kind of guidance there is, ergo, what is demanded, and also to use interviews to determine how things are actually done in practice. The guidelines and real operations are not always on the same level in reality, thus they both had to be studied.

As qualitative interviews rely on subjectivity, they cannot produce pure objective knowledge. It must be noticed that human conversational processes, ways of talking, describing past experiences and self-understandings are always present in interviews. Nevertheless, it is possible to strive for objectivity to some extent by avoiding bias and influence on interviewees and demonstrate expertise or professionality, thus attaining some degree of objectivity. (Brinkmann, 2013, pages 142-143.) One must therefore be aware of the subjectivity of the interviews in order to make them as objective as possible.

Interviews can have a lack of reliability because they involve human judgment. They are depended on unique meetings between interviewer and interviewee, and empirical interview materials can be interpreted in different ways depending on the interpreter. However, it does not mean that interpretations and analyses cannot be assessed or discussed rationally. It is possible to strive for some degree of reliability, for example, if different people answer to the question with same conclusions or statements, qualitative interviews can be reliable to some extent. (Brinkmann, 2013, pages 143-144.)

The aim was to draft the interview questions in such a way that they would not lead to answers. All generated questions were commented by few company's professional employees before they were finalized, and these employees were excluded from the interviews. Interviewees were selected in advance in order to know that they understand what is being discussed and they have experience with the issue. The author tried not to influence on answers during interviewing and focused on keeping the course of the interview the same for all interviewees. Nevertheless, there are multiple things that can have effect on reliability of interviews. Communication and personal ways to express things can have effect as well as experience and attitude of the interviewee. Bravery to discuss about problems or admit that there is challenges or problems relating to own practices or project can affect the reliability and also stress level about having interview can affect. People are different, thus subjectivity seems to impair the reliability of the results. However, similar responses increase the reliability of the interviews and the large number of interviews supports the increase in reliability. Whether the interviewee understood the matter correctly or what kind of theoretical or practical knowledge he or she has in advance can affect the answers. In the same way, the author's own interpretation of the interviewers' expression as well as the translation work into English can affect the reliability of the interview results. The Table 6 shown earlier in the subchapter 3.2 was created to provide background information about interviews and interviewees and that way support the reliability of the interviews. However, interviews play a major role in the research part of this thesis, and interview questions were created based on literature review and theoretical framework.

6.2 Recommendations for future research

As the solution proposition of this thesis provides general description about the developed process between design management and procurement, the implementation of the process should be conducted and empirical research about its functionality would be needed. Some

kind of measurement would be required for the solution proposition considering that how much the supply chain between design management and procurement is improved with it in practice. One should be able to somehow measure the supply of plans at right time for the procurement and the correspondence of their content to the required content and level of planning. A means should be developed to compare the effectiveness of the proposed solution with other ways of implementing the supply chain between design management and procurement. For example, if only design packages are used in the process and preliminary procurement packages are not used but procurements are distributed freely later or design packages are not used but design work is managed directly by procurement basis and with procurement packages. Empirical research on this issue is desired.

Furthermore, during the research, it emerged that while Kruus & al. (2006) SUKE-model has standardized design packages, also some critical and recurring procurement packages could be standardized based on the future research. One should examine what kind of procurement packages are recurring in business premises construction projects and what are the most common critical path procurement packages. In the context of standardization of the packages, the required plans and the level of planning for them could be defined at general level based on which procurement formats are most commonly used for them.

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Appendixes

Appendix 1. Standard design packages of building technology. 2 pages. (Customized based on reference: Kruus & al., 2006, pages 66-67.)

Appendix 2. The final interview frame and questions.

Appendix 3. Procurement package card template.

Appendix 4. A coordination tool for design and procurement packages in detailed design phase.

Appendix 1. Standard design packages of building technology

Standard design packages of building technology The content according to Talo 2000 nomenclature. Numbering in chronological order.		
Designs/Plans	**Design packages**	**Procurements**
Master plan Master drawings Space concepts, model room Building specification **Detailed designs which will be supplemented** Floor plans Sections	**0 Plans which will be supplemented**	
	1 Earth-moving plans	
(Courtyard drawing) (Area structures)	Clearing and demolition work Excavation and filling Drainage structures Chosen area structures	Earth-moving works
	2 Demolition plans and structure parts to be preserved by sections	
Drawings about present condition Demolition plan	Demolition of building structures Demolition of space structures Special demolitions (agreed) Preserved space equipment and permanent fixtures Protections	Demolition work
	3 Foundation and base floor plans by sections	
Foundation plans Base floor plans	Foundation Base floors Special foundation and base floor structures (agreed)	Foundation work Base floor concrete works
	4 Elevators and other means of transportation	Elevator work
Elevator plans Elevator shaft plans		Works related to other means of transportation
	5 Building frame plans by sections	
Building frame plans	Fallout shelters Load bearing walls, columns, beams, intermediate floors, roofs Frame stairs Special frame structures (agreed)	Building frame works Element work
Façade sections	**6 Façade and external level plans by section**	Structural work of façade
Façade design details Window and external door layouts Façade equipment plan Façade roofs Balcony plans	Exterior walls, windows, external doors, façade equipment Balconies, façade roofs Special façade and façade roof structure plans	Surface work of façade Equipment works of façade Sheet metal claddings Windows and external doors work External level roofing External paintings

Designs/Plans	Design packages	Procurements
Roof drawing	**7 Roof plans by sections**	Waterproofing work
Roof equipment plans Glass roof plans	Roof, eaves, roofing, roof equipment Glass roof structures, skylight windows and hatches Special roof structures (agreed)	Roof structure work Ventilation engine room work Roof equipment work
Floor plans	**8 Space distribution plans by areas**	Partition wall work
Partition wall layouts Internal doors layouts Door catalogue	Partition walls, glass partition walls, special partition walls Space railings, interior doors, special doors, space stairs Special space distribution parts (agreed)	Interior door work Special door work Light stairs work
Space module plans	**9 Plans about industrialized space modules (entities)**	Space module work
	Bathrooms, refrigerating rooms, space saunas HVAC-space modules, ventilation panels Special (agreed) space entities	Space module subcontracts
Working platform plans etc.	**10 Plans about other spaces by areas**	Steel structure work
Fireplace plans	Working platforms and passage structures Fireplaces and furnace construction Special (agreed) space parts	
Floor drawings	**11 Space surface plans by space groups**	
Suspended ceiling drawings	Floor surface structures and coverings Ceiling structures Interior wall and ceiling surfaces Special (agreed) space surfaces	Internal paintings Floor covering work Suspended ceiling work Battening
Fixture plans	**12 Space equipment plans by space groups**	Permanent fixture work
Equipment plans Device catalogue Plans about guiding	Special permanent fixtures Standard permanent fixtures Equipment, devices Space guiding Special (agreed) equipment	Equipment work Guiding work
	13 Plans about space devices	
Device catalogue Device placement	Kitchen devices Laundry devices Other devices	Kitchen device procurement Laundry device procurement
Area plans	**14 Area plans**	
	Area coverings, equipment and structures	Courtyard works Area equipment works

Appendix 2. The final interview frame and questions

- Background questions
    1. *Job title and department?*
    2. *Describe what kind of background and experience you have in the processes between design management and procurement?*

- Company's present practices
    1. *Describe how the supply chain process between design management and procurement currently works in projects? What kind of process has been used in the projects you have been involved in? Does the company have common policies and guidelines on the matter?*
    2. *How is the design schedule created and what does it contain? Which parties have been involved and who should be?*
    3. *How is the procurement strategy and plan created, and what does it contain? Which parties have been involved and who should be?*
    4. *Is there been coordination or cross checking of design schedule, design packages and procurement packages? If there is, in what level?*
    5. *What information, guidelines, instructions or tools you would have liked to have in use, but you didn't have?*
    6. *Does the company have standardized levels of development considering building information modeling? Would it be useful in terms of procurement and utilization of the building information model? Is there company's transcription in use in building information modeling for quantity takeoff?*
    7. *Is the design work managed currently by building information modeling?*
    8. *At what stage are design documents and plans currently available for procurement for making procurements?*

- Challenges and problems
    1. *What are the current challenges and problems between design management and procurement?*
    2. *Is there something that makes waste in the process between design management and procurement?*
    3. *Are the design packages and procurement packages synchronized, ergo, do they interact? If not, why not?*
    4. *In what position are we now with the subject, what would be the target and what should we do about it?*

- Development propositions
    1. *What is the process by which design management can produce plans for procurement at right time?*
    2. *What kind of plans procurement needs to be able to make proper invitations for tenders?*
    3. *What are the needs of design management and procurement in order to make fluent working supply chain process?*
    4. *Should there be collaboration between design management and procurement regarding design schedule, design packages, procurement strategy and plan as well as procurement packages? In what way?*
    5. *How could building information modeling be utilized between design management and procurement? Is there a need for more guidance and support on this topic or need for a process description?*

Appendix 3. Procurement package card template

Procurement package card

The name of the procurement package

The content of procurement package (contract boundaries / other limitations)

The schedule of procurement package

Inspection about the design package:
Inspection about the procurement package:
Invitation to tenders:
Tender:
Negotiations:
Contract:
Delivery/Assembly:
Completed:

BIM: the required level of development

Plans and initial data required for the procurement as well as the need times for plans

Architect:
–
–
–
Structural design:
–
–
–
HVAC:
–
–
Electrical engineering:
–
–
Others:
–
–

Other considerations:

Appendix 4. A coordination tool for design and procurement packages in detailed design phase